LETTERS

THE HEALTH OF WORKERS

I was given a copy of the April, 2003 issue of the American Journal of Public Health. The cover photo, in addition to being an excellent piece of photography, also accurately depicts the feelings of our membership in regard to health benefits. Your decision to make workers' health a focal point of the issue was very welcome to us.

This cover photo was taken on April 24, 2002, when over 10 000 of our 34 000 members gathered to tell our employer, the Metropolitan Transit Authority, that we want safer working conditions, good wages, and health benefits, as well as respect and dignity on the job.

This was the second rally, the first being in March of 2001 on the same subject. Another rally in 2002 of over 14 000 issued the same message.

We feel that this mobilization of the membership in our city streets served the purpose of reinforcing our membership's appreciation, as well as that of the riding public, of the crucial importance of both workplace safety and health care security.

I am glad to report to your readers that we successfully convinced the MTA of our message—we negotiated a three year agreement that strengthened safety rules substantially and not only maintained our current level of benefits, but increased it in the areas of mental health and child care.

At the same time we were winning these basic health rights for our members, our union has been participating fully in the struggle for universal health care for everyone. It is our view that health care is a right, not a privilege.

Thank you for featuring our membership so that the readership of AJPH and the membership of the American Public Health Association is more informed of these issues. ■

Roger Toussaint, President
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LETTERS

COMMUNICATING COMPLEX INFORMATION: THE INTERPRETATION OF STATISTICAL INTERACTION IN MULTIPLE LOGISTIC REGRESSION ANALYSIS

With the availability of statistical software packages, more and more complex statistical models can be easily applied to research data. It is crucial that care be taken when communicating complex information from these statistical models. Just like in a general linear model analysis, where the coefficient for an interaction term does not have a "slope" interpretation, when an interaction effect is included in a multiple logistic regression model, the odds ratios (ORs) based on coefficient estimates are not all meaningful, and the correct ORs to report need to be recalculated.

In a recent article, Forsyth et al.[1] studied the effect of HIV voluntary counseling and testing on reproduction planning among adults in 2 developing countries. A statistical interaction between pregnancy intention at baseline and HIV serostatus was included in the logistic regression models and was found to be statistically significant among women. The authors reported an OR of 0.1 for the interaction effect and stated that the women more likely to be pregnant were not using contraceptives (OR=0.1) and were HIV infected (OR=3.0), whereas partner pregnancy rates were not different by HIV serostatus among men. The article concluded that "HIV diagnosis may influence reproduction planning for women but not for men."

Based on Tables 3 and 5, the logistic regression model is of the following form:

$$1)\quad \text{logit}(P_{preg}) = \beta_0 + \beta_{\text{planned}} \times I_{\text{planned}} + \beta_{\text{infected}} \times I_{\text{infected}} + \beta_{(\text{planned}\times\text{infected})} \times I_{(\text{planned}\times\text{infected})},$$

where βs are logistic regression coefficients and I_{planned} is an indicator variable that equals 1 when the woman is planning a pregnancy; it equals 0 when she is not. Same for I_{infected}, an indicator variable for HIV infected nor not.

On the basis of the results (Table 3), the estimates of the coefficients for the multiple logistic regression model for women were:

$$2)\quad \hat{\beta}_{\text{infected}} = \ln(\hat{OR}_{\text{infected}}) = \ln(3.0) = 1.0986,$$

$$3)\quad \hat{\beta}_{\text{planned}} = \ln(\hat{OR}_{\text{planned}}) = \ln(1.7) = 0.5306,$$

$$4)\quad \hat{\beta}_{(\text{planned}\times\text{infected})} = \ln(\hat{OR}_{(\text{planned}\times\text{infected})}) = \ln(0.1) = -2.3026.$$

Because of the interaction effect, the meaningful ORs for comparisons need to be derived as follows. For women who were not planning a pregnancy, the odds ratio for those with HIV infection versus without infection is

$$5)\quad \hat{OR}_1 = \frac{Odds \text{ for } (I_{\text{planned}} = 0 \text{ and } I_{\text{infected}} = 1)}{Odds \text{ for } (I_{\text{planned}} = 0 \text{ and } I_{\text{infected}} = 0)} = \exp(\hat{\beta}_{\text{infected}}) = \exp(1.0986) = 3.0.$$

For women who were planning a pregnancy, the odds ratio for those with HIV infection versus without is

$$6)\quad \hat{OR}_2 = \frac{Odds \text{ for } (I_{\text{planned}} = 1 \text{ and } I_{\text{infected}} = 1)}{Odds \text{ for } (I_{\text{planned}} = 1 \text{ and } I_{\text{infected}} = 0)} = \exp(\hat{\beta}_{\text{infected}} + \hat{\beta}_{(\text{planned}\times\text{infected})}) = \exp(1.0986 - 2.3026) = 0.3.$$

For women who were not HIV infected, the odds ratio for women who were planning a pregnancy versus those who were not is

$$7)\quad \hat{OR}_3 = \frac{Odds \text{ for } (I_{\text{planned}} = 1 \text{ and } I_{\text{infected}} = 0)}{Odds \text{ for } (I_{\text{planned}} = 0 \text{ and } I_{\text{infected}} = 0)} = \exp(\hat{\beta}_{\text{planned}}) = \exp(0.5306) = 1.7.$$

For women who were infected, the odds ratio for women who were planning a pregnancy versus those who were not is

$$8)\quad \hat{OR}_4 = \frac{Odds \text{ for } (I_{\text{planned}} = 1 \text{ and } I_{\text{infected}} = 1)}{Odds \text{ for } (I_{\text{planned}} = 0 \text{ and } I_{\text{infected}} = 1)} = \exp(\hat{\beta}_{\text{planned}} + \hat{\beta}_{(\text{planned}\times\text{infected})}) = \exp(0.5306 - 2.3026) = 0.17.$$

For a comparison of women who were infected and were planning a pregnancy versus those who were not infected and were not planning a pregnancy, the odds ratio is

$$9)\quad \hat{OR}_5 = \frac{Odds \text{ for } (I_{\text{planned}} = 1 \text{ and } I_{\text{infected}} = 1)}{Odds \text{ for } (I_{\text{planned}} = 0 \text{ and } I_{\text{infected}} = 0)} = \exp(\hat{\beta}_{\text{planned}} + \hat{\beta}_{\text{infected}} + \hat{\beta}_{(\text{planned}\times\text{infected})}) = \exp(0.5306 + 1.0986 - 2.3026) = 0.51.$$

Whether women who were more likely to be pregnant were not using contraceptives seems to depend on their HIV infection status; whether they were more likely to be HIV infected depends on their pregnancy planning status.

Similarly, based on Table 5, the corresponding estimates of coefficients for men were

$$10)\ \hat{\beta}_{\text{infected}} = \ln(\hat{OR}_{\text{infected}}) = \ln(1.6) = 0.47,$$

$$11)\ \hat{\beta}_{\text{planned}} = \ln(\hat{OR}_{\text{planned}}) = \ln(1.2) = 0.1823,$$

$$12)\ \hat{\beta}_{(\text{planned}\times\text{infected})} = \ln(\hat{OR}_{(\text{planned}\times\text{infected})}) = \ln(0.5) = -0.6931,$$

and the corresponding ORs for partner pregnancy can be calculated as

$\hat{OR}_1 = 1.6$, $\hat{OR}_2 = 0.80$, $\hat{OR}_3 = 1.2$, $\hat{OR}_4 = 0.60$, and $\hat{OR}_5 = 0.47$.

Even though the statistical significance of these comparisons will depend on the correlations among the coefficient estimates, which were not available from the article, both men and women seem to show very similar patterns. Among those who were not planning a pregnancy, HIV infection status tended to increase the odds of a pregnancy, whereas among those who had planned a pregnancy, the HIV infection status tended to decrease the odds of a pregnancy.

Care needs to be taken when interpreting and reporting results from complex statistical models. To correctly interpret the results from a multiple logistic regression analysis and arrive at meaningful conclusions, it is crucial that appropriate steps be taken to properly incorporate statistical interaction effect. ■

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Acknowledgements

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References

1. Forsyth A, Coates T, Grinstead O, et al. HIV infection and pregnancy status among adults attending voluntary counseling and testing in 2 developing countries. *Am J Public Health.* 2002;92(11): 1795–1800.

FORSYTH RESPONDS

We thank Chen for correctly pointing out a lack of precision in sections of our manuscript[1] regarding an interpretation of a multiple logistic regression model of pregnancy outcomes 6 months after HIV diagnosis among women in 2 developing countries. We hope that our global interpretation of a statistical analysis of women's intentions to become pregnant and HIV diagnosis is mitigated in 2 ways. First, we reported no univariate differences in women's pregnancy outcome by HIV diagnosis in Table 2 of our paper. Second, in the results section, we interpreted properly the interaction coefficients showing that, "women who had received a recent HIV diagnosis and had expressed the intention to become pregnant before HIV testing were less likely to be pregnant at follow-up." We appreciate the opportunity to clarify that the positive relationship between pregnancy outcome and HIV diagnosis observed in Table 3 pertained only to those without pregnancy plans before receiving voluntary HIV counseling and testing (VCT), and not to all women in the study.

Chen takes issue with our claim that "HIV diagnosis may influence reproduction planning for women but not for men," arguing that the "men and women show very similar patterns." Determining the statistical significance of these differences would require testing models that included gender with and without gender interactions. We did not pursue this route. We acknowledge that there were broad, qualitative similarities between men and women in our analyses, but we maintain that the quantitative findings indicated that the interaction effects of pregnancy intentions and HIV diagnosis were statistically significant for women but not for men.

We concur with Chen that regression models with interaction terms require careful interpretation of generated coefficients and great precision in communicating complex results to readers. ■

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Reference

1. Forsyth A, Coates T, Grinstead O, et al. HIV infection and pregnancy status among adults attending voluntary counseling and testing in 2 developing countries. *Am J Public Health.* 2002;92(11): 1795–1800.

SCREENING MAMMOGRAPHY IN ASIAN AMERICAN WOMEN

A recent article by Leung et al.,[1] concluding that annual, population-based screening mammograms are not justified in Hong Kong, would seem to have implications for screening of Asian women in Western countries. In US Asian/Pacific Islander women aged 50 years or older, for example, 1996 breast cancer incidence and mortality rates were 126.4 and 32.7 per 100 000, respectively,[2] similar to rates in Hong Kong. Following the calculations described by Leung et al., we calculated a screening prevalence of 149.8 per 100 000 and assumed 95% sensitivity, 99.1% specificity, and an 8% complication rate among 18.6% of healthy women receiving biopsies after a false-positive result. Among 100 000 women screened annually for 10 years, we would expect 8987 of 10 410 positive results to be false, with 134 of these women suffering biopsy complications. If 100 000 women were screened annually for 10 years, 65 breast cancer deaths would be prevented; 1529 women would need to be screened over 10 years to prevent 1 breast cancer death (although the mortality benefit might be underestimated if the lower breast cancer mortality rate in Asian American women reflects earlier detection).

Relaxing screening guidelines for Asian Americans might be justified on the basis of these calculations. On the other hand, screening guidelines already in place in the United States, controversial or not, raise the standard of our expectation: any cancer death resulting from late detection is one that should have been prevented. Moreover, assigning low-risk status on the basis of ethnicity raises another concern—that it might contribute to a belief that Asian women are inherently at lower risk for breast cancer, when they are not. Breast cancer rates are known to rise in Asian migrants to Western countries,[3] and they are rising with "Westernization" in Asian countries as well.[4,5] Ethnicity is merely a surrogate for the suspected but largely unidentified factors that actually do confer lower risk.

From a research perspective, what is needed is a better characterization of the rapid transition in breast cancer risk that Asian women in Western and Asian countries are undergoing and a better understanding of the social, economic, cultural, and biological factors contributing to this increase in risk. Ideally, a clearer understanding of these issues will contribute to preventive strategies and efforts toward more targeted screening.

With respect to implications for screening, Asian American women as a group clearly stand to benefit less by following guidelines designed for a higher-risk population. But as long as our conception of their low-risk status rests on their ethnicity, without a clear understanding of the factors underlying their lower risk, a wholesale relaxation of guidelines for only this subset of the population is problematic. Decisions on how strictly to adhere to standard screening guidelines might best be left to individual physicians and their patients. ■

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References

1. Leung GM, Lam TH, Thach TQ, Hedley AJ. Will screening mammography in the East do more harm than good? *Am J Public Health.* 2002;92:1841–1846.

2. National Cancer Institute, Division of Cancer Control and Population Sciences, Surveillance Research Program, Cancer Statistics Branch. Surveillance, Epidemiology, and End Results (SEER) Program Public-Use Data (1973–1999). Released April 2002, based on the November 2001 submission. Available at: http://www.seer.cancer.gov/publicdata/ (registration required).

3. Thomas DB, Karagas MR. Migrant studies. In: Schottenfeld D, Fraumeni JF Jr, eds. *Cancer Epidemiology and Prevention.* 2nd ed. New York, NY: Oxford University Press; 1996:236.

4. Chen CJ, You SL, Lin LH, Hsu WL, Yang YW. Cancer epidemiology and control in Taiwan: a brief review. *Jpn J Clin Oncol.* 2002;32(suppl 1):S66–S81.

5. Wakai K, Suzuki S, Ohno Y, Kawamura T, Tamakoshi A, Aoki R. Epidemiology of breast cancer in Japan. *Int J Epidemiol.* 1995;24:285–291.

LEUNG ET AL. RESPOND

We agree with Tseng and Fang's extrapolation of our calculations to Asian Americans but differ on their interpretation of the results. First, while Asian Americans suffered fewer breast cancer–related deaths, their mortality rates relative to incidence for women aged 50 years and older in 1996 (32.7/126.4 per 100 000 = 0.26) were in fact higher than those reported for Whites (78.2/367.4 per 100 000 = 0.21).[1]

Second, their assertion that "any cancer death resulting from late detection is one that should have been prevented" is misleading. There are 2 kinds of early detection in cancer control. Screening of asymptomatic individuals is one strategy. There is evidence that shows breast self-examination in well women does not reduce mortality,[2] and the literature is controversial regarding whether mass mammography screening benefits White populations.[3] The other type of early detection—prompt recognition of symptoms, quick access to health care, and early diagnosis—followed by optimal treatment[4] may hold much greater promise in reducing breast cancer mortality.

Third, we concur that the effects of Westernization have led to increased breast cancer incidence in Asian populations,[5] but the absolute rates remain less than one half to one third the corresponding rates for White Americans. Ethnicity and place of origin of Asian Americans therefore need to be taken into account in the overall assessment of risk for breast cancer, just as age, family history, and past history of breast pathology are included. While a "wholesale relaxation of guidelines" for Asian Americans may be unwarranted, disregarding both lack of benefit and harm from screening mammography is unethical. However, we agree that we must remain vigilant in monitoring breast cancer trends and be prepared to reevaluate the current recommendations if and when significant changes occur.

We agree that research should be directed at identifying factors responsible for the different risks in Western versus Asian women. Preliminary data[6] support the hypothesis that hormone-dependent malignancies have their origin in intrauterine life, where higher

levels of pregnancy hormones favor the generation of more susceptible stem cells with compromised genomic stability. This may be linked to the observation that it takes more than 2 generations for the incidence of breast cancer in Asian immigrants to the West to reach the higher rates prevailing in the host population. Future research should focus on lifestyle or other environmental determinants of pregnancy hormone levels and possible mechanisms by which they may influence carcinogenesis.

All screening potentially causes harm. Indiscriminate mass screening of well people at low risk for the disease can cause large-scale harm. Clinicians and public health providers must heed Hippocrates' dictum—*Primum non nocere.* ■

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References

1. National Cancer Institute. SEER incidence and US mortality statistics. Available at: http://seer.cancer.gov/canques. Accessed December 17, 2002.

2. Thomas DB, Gao DL, Ray RM, et al. Randomized trial of breast self-examination in Shanghai: final results. *J Natl Cancer Inst.* 2002;94:1445–1457.

3. National Cancer Institute. PDQ cancer information summaries: screening/detection for breast cancer. Available at: http://www.nci.nih.gov/cancer_information/doc_pdq.aspx?version=1&summaryid=208_04723. Accessed December 17, 2002.

4. Gillis CR, Hole DJ. Survival outcome of care by specialist surgeons in breast cancer: a study of 3786 patients in the west of Scotland. *BMJ.* 1996;312:145–148.

5. Leung GM, Thach TQ, Lam TH, et al. Trends in breast cancer incidence in Hong Kong between 1973 and 1999: an age-period-cohort analysis. *Br J Cancer.* 2002;87:982–988.

6. Lipworth L, Hsieh CC, Wide L, et al. Maternal pregnancy hormone levels in an area with a high incidence (Boston, USA) and in an area with a low incidence (Shanghai, China) of breast cancer. *Br J Cancer.* 1999;79:7–12.

HEALTHY COMMUNITIES: A NATURAL ALLY FOR COMMUNITY-ORIENTED PRIMARY CARE

As guest editors for the forum on community-oriented primary care (COPC) and as authors of an article that traces the conceptual roots of COPC and its proposed future role as an "important conceptual framework" for practice, Mullan and Epstein note the existence of various movements in health care that provide natural allies for COPC.[1] We would like to suggest an additional ally—the Healthy Communities movement.

Formulated almost 2 decades ago, the principles of Healthy Communities (HC)[2] emphasize a democratic approach to addressing community problems that focuses on strengths.[3,4] In merging the COPC and HC approaches to engaging community members, we have discovered a positive synergy. While both approaches spring from a common framework of health broadly defined, the language of HC is more lay friendly and broadly participatory. It begins with members of the lay and professional communities imagining what their neighborhoods and communities can become. This step of creating a shared vision, explicit in HC but only implicit in COPC, is an important element of the process. It develops a common bond and identifies areas of shared concerns.[5]

Mullan and Epstein note, "The idea of community is the core element [of COPC] and the point of departure for the COPC process."[1(p1750)] Despite the renewed emphasis on community engagement that has appeared in the COPC literature,[6,7] however, few articles do more than encourage clinicians to work with community members. Indeed, the emphasis has been placed on the epidemiological skills needed to describe a community and identify its health problems and risks; the skills needed to play a collaborative leadership role in this process are seldom described adequately. One of the contributions of the HC literature is discussion about building effective partnerships among the many players, not simply the health care facility and community members, and the acknowledgement that relationship building and democratic decisionmaking take time. This literature specifically addresses the importance of attention to community-building processes, another area that the COPC literature often finesses. Initiatives that grow from an explicit HC framework recognize the importance of learning to live with—indeed, to value—the tension inherent in balancing process and outcomes simultaneously.[8]

One example of the allied COPC–HC approach is occurring in central Massachusetts, where a family medicine practice hosted a monthly 8-part discussion series on the principles and precepts of COPC. At the series' conclusion, organizers made a purposeful, subtle shift from using the COPC paradigm exclusively to incorporating the principles and practice of HC as a way to engage additional citizens. The result has been a community–professional partnership called the East Quabbin Alliance (EQUAL), which has realized remarkable successes in the areas of adolescent and environmental health. The group regularly engages additional citizens and remains closely identified with the family medicine practice.

The notion that other movements can be natural allies of COPC is an important one that practitioners who seek to amalgamate primary care and public health should recognize. As Mullan and Epstein note, while COPC appeals on the basis of practicality and principle, it has not become the prevalent mode of practice in health systems.[1] All of us who work in COPC would be wise to seek allies that can help strengthen our efforts. We have found one in Healthy Communities.[9] ■

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References

1. Mullan F, Epstein L. Community-oriented primary care: new relevance in a changing world. *Am J Public Health.* 2002;92:1748–1755.

2. Hancock T, Duhl L. *Healthy Cities: Promoting Health in the Urban Context.* Copenhagen, Denmark:

FADL Publishers; 1986. World Health Organization Healthy Cities Paper No. 1.

3. Wolff T. Healthy Communities Massachusetts: one vision of civic democracy. *Municipal Advocate.* Spring 1995:22–24.

4. Flower J. Bridges, not walls—building healthier communities. *Healthc Forum J.* 1993;36(4):65–73.

5. Norris T, Pittman M. The healthy communities movement and the coalition for healthier cities and communities. *Public Health Rep.* 2000;115:118–124.

6. Cashman SB, Fulmer HS, Staples L. Community health: beyond care for individuals. *Soc Policy.* Summer 1994:52–62.

7. Rhyne R, Cashman SB, Kantrowitz M. Introduction and overview of COPC. In: Rhyne R, Bogue R, Kukulka G, Fulmer H, eds. *Community Oriented Primary Care: Health Care for the 21st Century.* Washington, DC: American Public Health Association; 1998: chap 1.

8. Wilcox R, Knapp A. Building communities that create health. *Public Health Rep.* 2000;115:139–143.

9. Kinder G, Cashman SB, Seifer S, Inouye A, Hagopian A. Integrating healthy communities concepts into health professions training. *Public Health Rep.* 2000;115:266–270.

MULLAN RESPONDS

Cashman and Stenger's letter calling attention to the Healthy Communities program as a friendly amendment to the practice of COPC is welcome. There are a number of concepts that merge public health practice principles with clinical practice for the purpose of furthering community health. Most of these movements share common values and strategies. Healthy Communities is clearly compatible with COPC, and Cashman and Stenger are to be commended for their efforts in this area. ■

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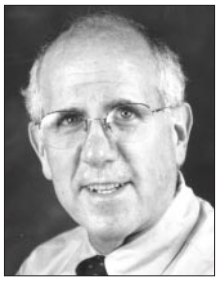
EDITOR'S CHOICE



Slums, Slum Dwellers, and Health

Although this issue of the Journal is focused on the connections between the built environment and health in the developed world, these links are even more relevant in the developing world, where billions of the world's poor live in precarious housing submarkets known as slums.

While their physical forms vary by place and over time, slums are uniformly characterized by inadequate provision of basic infrastructure and public services necessary to sustain health, such as water, sanitation, and drainage. Buildings made of flimsy materials are prone to ignite, frequently collapse, and offer scant protection against the elements, leaving their residents vulnerable to injury, violence, illness, and death. Further, since many of these settlements are illegal, slum dwellers often have no official addresses and are commonly denied basic rights and entitlements, including the right to vote, public education, and health care.

At the Millennium Summit in September 2000, the states of the United Nations (UN) reaffirmed their commitment to working toward a world in which sustainable development and elimination of poverty would have the highest priority (see http://www.unmilleniumproject.org). Eight Millennium Development Goals (MDGs) grew out of the agreements and resolutions, and they have since become the basis of a global effort led by UN Secretary General Kofi Annan to address the extensive environmental degradation and health problems of slums and slum dwellers. To provide planning and policy substance to this effort, the Millennium Development Project was organized to advise the UN on how to implement the MDGs. To facilitate the Project's work, the challenges of the 8 MDGs were assigned to 10 task forces consisting of outside experts, UN specialists, and representatives of relevant international organizations.

Task Force 8—the Task Force on Improving the Lives of Slum Dwellers—was specifically charged with developing plans to improve the lives of at least 100 million slum dwellers by 2020, yet more far-reaching work will clearly be needed. At present, approximately 1 billion people in a global population of 6 billion live in urban slums. By 2030, when the global population is expected to have increased to 8 billion, the number of slum dwellers will double to 2 billion. Half of the expected population increase over the next 3 decades will consist of slum dwellers in impoverished cities, particularly in sub-Saharan Africa, Latin America, and South Central Asia.

Slums are not "the problem." Rather, they are the spatial manifestations of urban poverty, social exclusion, and inappropriate government policies. Indeed, slum settlements represent an active, grassroots attempt by the desperately poor to take care of themselves. The key to lasting improvements in the lives of slum dwellers globally is to end the divided city in which the rich live in isolated splendor next to—but worlds apart from—the poverty that surrounds them. Slum dwellers need help in making the transition from inhabitants of precarious urban settlements to citizens with full human rights and civic responsibilities. This transition will be abetted by adoption of the following principles: (1) fight poverty without fighting the poor; (2) fight squatting, not squatters, through improved capacity in urban physical planning; and (3) recognize the importance of gender as an explicit consideration in all slum improvement strategies, plans, programs, and activities. Task Force 8 seeks to mobilize the world community by means of feasible action plans focused on a broad urban development vision that will lead to lasting and meaningful improvements in the health and lives of slum dwellers. ■

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EDITORIALS

The Impact of the Built Environment on Health: An Emerging Field

The drive from my office to my suburban Atlanta home is all too familiar: it begins with a scary 7-lane thoroughfare, infamous for its strip malls, lack of sidewalks, and high pedestrian fatality rates; progresses to a jumble of connecting interstate highways packed with rush-hour traffic despite 12 or more roadway lanes; and ends with clusters of new, low-density, single-family residential developments lacking public parks, playgrounds, libraries, nearby stores or cafés, sidewalks, bicycle trails, and public transit. Adults and children in my neighborhood travel by private automobile to virtually all of their destinations, because they have no practical transportation alternatives.

We humans often assume that what is, had to be that way. In reality, virtually everything in our built environment is the way it is because someone designed it that way. Central Park is beautiful and appears "natural" precisely because Frederick Law Olmsted designed and built it that way. Roadside signs advertising fast food restaurants strike the eye because they are designed to catch the attention of someone rushing by at high speed. Because children cannot buy homes or vote for parks, bicycle trails, small local schools, or nearby ball fields, many new residential areas in America are built without such community assets.

Despite the fact that many humans accept the world as it is, we have a remarkable capacity to plan ahead, shape the future, and adapt to new settings. This capacity serves us well when we are trying to build new societies or solve public health dilemmas. Our parents and grandparents helped extend our life expectancy and build great cities such as New York and San Francisco that became hubs for culture and diversity. Our predecessors left us an economically strong and well-educated nation with a high standard of living seen as a model for many around the world.

The current generation now faces its own challenges. One challenge is to better understand the broad impact of our built environment on health and then to build future communities that promote physical and mental health. Public health has traditionally addressed the built environment to tackle specific health issues such as sanitation, lead paint, workplace safety, fire codes, and access for persons with disabilities. We now realize that how we design the built environment may hold tremendous potential for addressing many of the nation's greatest current public health concerns, including obesity, cardiovascular disease, diabetes, asthma, injury, depression, violence, and social inequities.

Some of our current zoning laws that block high-density, live–work–play developments derive from interventions that helped prevent the spread of tuberculosis and other infectious diseases in the 19th century. Public health–based zoning laws were also instrumental in separating homes and schools from the odors and toxic emissions of abattoirs and tanneries. In the 20th century, the automobile and accompanying highway construction enabled the growth of suburbs and the vast expansion of metropolitan areas. Rail and trolley lines declined, and by the late 1960s, the cores of most major cities were sapped of economic vitality and left with failing schools and rising crime rates. Government incentives that subsidized mortgages and highways encouraged home-building further out from urban areas. As the US population grew and density dropped, vast stretches of forests and farmland were lost in the creation of roadways, megamalls, megaschools, and megasubdivisions.

Even our environmental policies exacerbated the flow. In urban areas with extensive preexisting infrastructure, the past contamination of land presents future investors with real or potential liability risks, so many of these urban "brownfields" go unsalvaged. Despite the availability of over 10 000 vacant land parcels in New York City,[1] some city workers there have chosen to face commutes of 4 or more hours per day to subdivisions that replaced forests in northern Pennsylvania. This commuting pattern has led to the paving of vast quantities of landscape for roadways, cloverleaf intersections, and parking lots. At this point, the United States has paved a land area equivalent in size to the state of Georgia.[2,3]

Typical American families earn in real dollars roughly what they earned in the 1970s,[4] but we spend much more now on motorized transportation. From 1969 to 1995, the number of

private vehicles per household rose more than 50% to roughly one vehicle per licensed driver.[5] Cars are such a necessity for work and other daily activities in American life that most adults manage to find the $7000 or more per year to own, maintain, insure, and drive a car,[6] even if faced with choosing between health insurance and a car. Since 1970, the US population has increased 37%,[7,8] but the distance traveled by the nation's fleet of cars, motorcycles, sport-utility vehicles, and small trucks increased 143%.[9] From 1982 to 2000, the annual hours of highway traffic delay per person in urban areas increased from 16 hours to 62 hours per year.[10] And Americans now work more hours than people in any other major industrial nation in the world.[11] With rising private vehicle costs, long commutes, increasing traffic delays, and long work hours, it is easy to understand why parents may feel overwhelmed by time and financial demands.

Private motor vehicle transportation made necessary by extensive low-density land use has important implications for health: people are less active because they walk less, vehicle exhaust degrades air quality, motor vehicle injuries increase, and mental health and social capital are adversely affected. Decreased opportunities for children to incorporate physical activity into their daily lives, such as the inability to walk to school because of hazardous streets and long distances,[12] have contributed to a threefold increase in the prevalence of overweight children over the last 3 decades.[13]

America's aging population faces its own challenges. In this country, the number of people aged older than 65 will double by the year 2020.[14] Communities that are adequately designed for a young adult with fast reflexes can be unnavigable for an elderly person. As chronic diseases such as arthritis, obesity, and diabetes increase in prevalence, the need becomes paramount for communities where elderly and disabled persons (and young persons with few resources) can function well and contribute to society without needing to own an automobile.

As Hippocrates, the Romans, and Jung knew, our physical environment affects our physical and mental health. We physicians focus well on our patients as individuals with health problems, but when so many of our patients have the same problems, such as cardiovascular disease, diabetes, and depression, we must realize that their poor health is not caused only by a lack of discipline but may be the result of the built environments in which we live.

It is time for a shift to communities intentionally designed to facilitate physical and mental well-being. To effect this change, we need to draw upon the unique ability of humans to plan creatively for healthy communities. The first step is to understand better the elements of the built environment that promote health. From the limited research to date, the public health community knows that some environments encourage walking, biking, and social interaction more than others do[15,16]; that many traffic injuries can be prevented[17]; that increasing motor vehicle exhaust exacerbates pulmonary disease[18]; and that the presence of neighborhood liquor stores increases alcohol consumption and associated adverse health consequences.[19] But overall, there is still much to learn about the effects of the built environment on health. To address the multitude of questions, public health professionals must work closely with experts in other fields: architects, planners, policymakers, social scientists, traffic engineers, developers, law enforcement officers, economists, social marketers, and others.

With its focus on the built environment and health, this issue of the Journal strives to promote this emerging field of research. Bringing together experts from many disciplines, this issue includes research on the relationship between the way we build our communities and walking/biking (Cervero, Powell, Saelens, Pucher, Bonnefoy), mental health (Kaplan, Leventhal), traffic safety (Evans, Retting, Egan, Ewing, Lucy), children's health (Everett), minority health (Duran), affordable housing (Garb, Saegert), crime (Carter), government policies and law (Perdue, Buzbee, Ashe, Librett), economics (Burchell), air quality (Samet, Künzli), and water quality (Greenberg, Gaffield). Other articles examine the effects of local community interventions (Dickerson, Staunton, Semenza, Wilson), the connection between the Smart Growth movement and health (Geller), the "sense of place" as a public health construct (Frumkin), and key questions for future research (Dannenberg, Srinivasan).

Many aspects of the built environment will resist rapid change, even when research has adequately revealed key aspects of healthy communities. Efforts to improve pedestrian facilities, preserve green space, and upgrade public transportation are under way in many communities. Whereas our generation may reap some benefits from the new field of the built environment and health, with a little vision and a lot of good science and hard work, our children and grandchildren will be able to walk or bicycle home from their workplaces through attractive communities designed to promote the physical and mental health of all people. ■

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References

1. *A Time to Build: Report of the Manhattan Borough President's Task Force on Affordable Housing.* New York, NY: Office of the President, Borough of Manhattan; January 2000. Available at: http://www.cvfieldsmbp.org/time2bld/time2bld.pdf. Accessed June 5, 2003.

2. Brown LR. *Paving the Planet: Cars and Crops Competing for Land.* Washington, DC: Earth Policy Institute; February 2001. Available at: http://www.earth-policy.org/Alerts/Alert12.htm. Accessed June 5, 2003.

3. *States Ranked for Total Area, Land Area, and Water Area.* Wolfeboro, NH: NETSTATE, LLC; May 2003. Available at: http://www.netstate.com/states/tables/st_size.htm. Accessed June 5, 2003.

4. Schor JB. *The Overworked American: The Unexpected Decline of Leisure.* New York, NY: Basic Books; 1992:81.

5. *Summary of Travel Trends 1995 Nationwide Personal Transportation Survey.* Washington, DC: US Dept of Transportation, Federal Highway Administration; December 1999:28, Table 16. Available at: http://www-cta.ornl.gov/npts/1995/Doc/trends_report.pdf. Accessed June 5, 2003.

6. *Consumer Expenditures in 2001, Report 966.* Washington, DC: US Dept of Labor, Bureau of Labor Statistics; April 2003:3, Table A. Available at: http://www.bls.gov/cex/csxann01.pdf. Accessed June 5, 2003.

7. *Historical National Population Estimates: July 1, 1900 to July 1, 1991.* Washington, DC: US Census Bureau, Population Division, Population Estimates Program; 2000. Available at: http://eire.census.gov/popest/archives/pre1980/popclockest.txt. Accessed June 5, 2003.

8. *US Summary: 2000.* Washington, DC: US Census Bureau; July 2002: Table DP-1. Publication C2KPROF/00-US. Available at: http://www.census.gov/prod/2002pubs/c2kprof00-us.pdf. Accessed June 5, 2003.

9. *National Transportation Statistics 2002.* Washington, DC: US Dept of Transportation, Bureau of Transportation Statistics; December 2002: Table 1-32. Publication BTS02-08. Available at: http://www.bts.gov/publications/national_transportation_statistics/2002/html/table_01_32.html. Accessed May 29, 2003.

10. *2002 Urban Mobility Study.* College Station: Texas Transportation Institute; 2002. Available at: http://mobility.tamu.edu/ums/study/issues_measures/congested_roads.stm. Accessed June 4, 2003.

11. Organization for Economic Co-operation and Development (OECD). *OECD Employment Outlook.* Paris, France: OECD Publications; July 2002: 321–323. Available at: http://www1.oecd.org/publications/e-book/8102081E.PDF. Accessed June 5, 2003.

12. Centers for Disease Control and Prevention. Barriers to walking and biking to school—United States, 1999. *MMWR Morb Mortal Wkly Rep.* 2002; 51:701–704.

13. *Health, United States, 2002 With Chartbook on Trends in the Health of America.* Hyattsville, Md: US Dept of Health and Human Services, National Center for Health Statistics; 2002: Table 71. Available at: http://www.cdc.gov/nchs/data/hus/tables/2002/02hus071.pdf. Accessed June 5, 2003.

14. Kinsella K, Velkoff VA. *An Aging World: 2001, International Population Reports.* Washington, DC: US Census Bureau; 2001:127–128. US Census Bureau Series P95/01-1. Available at: http://www.census.gov/prod/2001pubs/p95-01-1.pdf. Accessed June 5, 2003.

15. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Ann Behav Med.* 2003;25: 80–91.

16. Putnam R. *Bowling Alone: The Collapse and Revival of American Community.* New York, NY: Simon and Schuster; 2000.

17. Area-wide urban traffic calming schemes: a meta-analysis of safety effects. *Accid Anal Prev.* 2001;33: 327–336.

18. Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma. *JAMA.* 2001;285:897–905.

19. The role of alcohol availability in alcohol consumption and alcohol problems. *Recent Dev Alcohol.* 1983;1: 285–302.

A New Traffic Safety Vision for the United States

Although the tragic events of September 11, 2001, are indelibly burnished into America's consciousness, the equally tragic events of October 2001, November 2001, December 2001, January 2002, and all subsequent months attract little public note. In a typical month, more Americans are killed on our roads than were killed by the terrorists.[1]

If we could stimulate new approaches to the problems of risk in road traffic as we did about airline security after 9/11, every year we could save many times more lives than were lost that day. This can be achieved with far less reduction of mobility, convenience, freedom, or civil rights than was produced by our ongoing response to 9/11.

THE UNITED STATES COMPARED WITH OTHER COUNTRIES

Over 42 000 people died on US roads in 2002.[1] If US traffic safety policy had kept pace with the policy in a number of other countries, the total would have been about 15 000 less.[2,3] While traffic fatalities from 1979 to 2000 declined by 50% in Canada,[4] 46% in Britain,[5] and 48% in Australia,[6] the decline in the United States was only 18%.[1] The better-performing countries did nothing remarkable, let alone draconian. They made many poor decisions. All their laws are passed by democratic legislative bodies answerable to electorates similar to ours. Prior to the 1970s, the United States was number one in the world in traffic safety.[7] As measured by the number of traffic deaths per million vehicles, the United States has slipped to13th place,[8] and is still sinking.

These better-performing countries view traffic deaths and injuries as much more of a public health problem than does the United States. They support more scientific research aimed at exploring and evaluating countermeasures. Sweden and Australia, with populations less than that of many US states, have more institutions devoted to road safety research than the United States. Rather than respecting technical knowledge, Americans have been persuaded that lawyers such as Ralph Nader and Joan Claybrook should guide policy.

ROLE OF US LITIGATION

Since the period when the United States was the world's safety leader, litigation here has acquired a role not approached anywhere else in the world. It has been spectacularly successful in directing focus away from the very countermeasures known to be successful in favor of vehicle factors that are of minor safety importance but are major sources of litigation wealth. The unbalanced nature of US safety policy is estimated to have killed well over 100 000 Americans in the last 2 decades.[2,3]

Airline safety has improved dramatically because it focuses mainly on preventing crashes, not on surviving them. We continue to kill so many people on our roads because of the mistaken belief that the main way to reduce these deaths is to make every crash marginally more survivable,

while largely accepting crashes as inevitable. Litigation can always point out that if the institutions that made the vehicle, road, or traffic control system had done something differently, the outcome of a crash would have been different. This is a trivial truism. Yet the litigation system skillfully transforms this truism into billions of dollars and deflects attention from the countermeasures that could really reduce harm.

THE 2 MOST IMPORTANT FACTORS

Of the over 42 000 traffic fatalities in 2002, 13 000 were drivers killed in single-vehicle crashes. The majority of victims—more than 29 000—were killed in crashes in which a driver other than the victim plays a role. This majority includes all pedestrians, passengers, and drivers killed in multiple-vehicle crashes.[1] My more than 30 years of traffic safety research leaves little doubt that the 2 factors that overwhelmingly determine an individual's risk in traffic are (1) the individual's behavior and (2) the behavior of other road users. The total risk in the nation is simply the summation of the risks to each of its citizens.

An individual's behavior is under his or her control. The more clearly road users acknowledge this, the safer they will be. Yet in the United States the very opposite message is repeatedly reinforced by media coverage of product liability trials. A high-profile trial may perhaps involve a driver who was severely injured (but not killed) after being ejected in a rollover crash. The public is informed that a tire manufacturer was responsible, but not informed that the driver was speeding and not wearing the legally required safety belt that would have made ejection nearly impossible. In some states, a jury must be kept ignorant of the fact that an injured plaintiff was not wearing a safety belt, even though such unsafe behavior is also illegal.[9] Instead of encouraging drivers to obey traffic laws, actions over which they have control, the US media coverage defines the problem in terms of manufacturing and design decisions over which drivers have no control.

The actions of other road users pose greater threats to our lives than those of terrorists. About 850 people are killed annually in the US by drives running red lights.[10] We are more likely to be killed by a driver running a red light and crashing into the side of our vehicle than by a terrorist bomb on an aircraft. There is no vehicle engineering change that can appreciably reduce this risk. It is a cruel hoax to imply otherwise—side airbags can produce no more than marginal risk reductions.

THE SOLUTION

The threat posed by other drivers can provide the key to more effective safety policy that will influence the behavior of all drivers. We accept invasive scrutiny of our persons and luggage before boarding an aircraft, even though we know we are not carrying a bomb. We realize that the only way to protect ourselves from someone else carrying a bomb is for all to be searched. A much larger risk reduction can be obtained if we agree to allow all vehicles, including our own, to be automatically monitored to reduce illegal driving.

Modern technology provides the means to automatically detect such illegal behaviors as running red lights, speeding, or tailgating. Cameras that automatically record the license plates of vehicles entering intersections after traffic lights have turned red are already reducing deaths and injuries in many countries (including limited applications in the United States).[10] Radar speed cameras have been widely deployed in Britain, Australia, and New Zealand.[10] Technology to measure the distance between cars has been developed and field-tested in Israel.[11]

To reap the enormous safety benefit that such technology can ultimately deliver, we must more warmly embrace a principal that is already implicitly accepted: that driving is a public, not a private, activity. The privacy that is rightly sacrosanct for private activities should not apply to driving because of the enormous threat it poses to others.

Airline pilots are denied privacy on the flight deck, and the speed and altitude of aircraft are routinely monitored. There is already universal acceptance that driving a ground vehicle is not an entirely private activity. Nobody advocates that anyone of any age has the right to drive a vehicle at any speed on either side of the road after consuming any quantity of any intoxicant. The breakthrough that is required is an agreement that other drivers pose so great a threat to our lives that we have the right to enforce traffic laws effectively. Assigning skilled police officers to monitor traffic is an ineffective misuse of valuable public resources. What humans do poorly, technology can do well at a microscopic fraction of the cost.

I believe that the public would warmly embrace the use of technology to effectively enforce traffic law if it were a central component of a fundamental change that included the following 4 policy changes.

1. Traffic law should have one purpose—to prevent injuries and deaths. Using traffic law to raise revenue brings it into disrepute, rendering it ineffective. Like other aspects of public health, traffic safety should be a government service supported by taxes. Given that traffic crashes cost our nation $200 billion per year,[12] public expenditures that reduce crashes pay handsome dividends.
2. Automatically detected minor violations should receive no punishment for first or very infrequent offenses. A gentle letter explaining the purpose of traffic law would enhance safety more than punishment. Repeat and more major violations would receive increasing fines. The goal is to increase public support for safer traffic, not to alienate average citizens.
3. All traffic fines should be kept in a separate account and distributed equally to all license holders as an annual bonus (perhaps just before Christmas). This could come with an upbeat letter from the secretary of state, expressing the hope that everyone would work together to ensure that the small bonus would be even smaller next year. Such a process would remind people, in a positive way, of the importance of traffic safety and reinforce the understanding that law enforcement's goal is to prevent harm, not to raise money.
4. Automatic monitoring associates law violations with vehicle license plates, not drivers. Law changes would be necessary to make owners responsible for taking care of citations, ideally by persuading the actual driver to respond. Serious driving offenses would continue to focus on the driver.

Unlike airport security, these proposals would save tens of thousands of lives annually and

would not inconvenience, delay, embarrass, or disadvantage any law-abiding citizen. ■

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References

1. National Highway Traffic Safety Administration. Fatality Analysis Reporting System. Available at: http://www-fars.nhtsa.dot.gov. Accessed August 2003.

2. Evans L. Traffic crashes. *Am Scientist.* 2002;90:244–253. Available at: http://americanscientist.org/articles/02articles/Evans.html. Accessed August 2003.

3. Evans L. Transportation safety. In: Hall RW, ed. *Handbook of Transportation Science.* 2nd ed. Norwell, Mass: Kluwer Academic Publishers; 2002:67–112.

4. Transport Canada. Canadian motor vehicle traffic collision statistics: 2000. Available at: http://www.tc.gc.ca/roadsafety/tp/tp3322/2000/en/page5_e.htm. Accessed August 2003.

5. Department for Transport. Transport statistics, Table 9.10. Road accidents and casualties: 1950–2001. Available at: http://www.transtat.dft.gov.uk/tables/tsgb02/9/download/91002.xls. Accessed August 2003.

6. Australian Transport Safety Bureau. Road safety statistics—fatalities. Available at: http://www.atsb.gov.au/road/stats/timefatl.cfm#roaduser. Accessed August 2003.

7. *MVMA Facts and Figures 1981.* Detroit, Mich: Motor Vehicle Manufacturers Association of the United States; 1981.

8. Organization for Economic Cooperation and Development. International road traffic and accident data. 2001. Available at: http://www.bast.de/htdocs/fachthemen/irtad/english/englisch.html. Accessed August 2003.

9. Blair D. Seat belt defense deserves a fair hearing in Texas [editorial]. *Houston Chronicle.* February 18, 2003: 19A.

10. Insurance Institute for Highway Safety. Officials nationwide give a green light to automated traffic enforcement—cameras to stop red light runners attract far more support than speed cameras. *Status Rep.* 2000; 35(3):1–3. Available at: http://www.highwaysafety.org/srpdfs/sr3503.pdf. Accessed August 2003.

11. Richter ED, Ben-David G, Ortiz R, Cortes J. A traffic monitoring and driver behavior modification system. USAID CDR Project C8-043, 1995. Also available at: http://www.ukspeedtraps.co.uk/speed01.htm. Accessed August 2003.

12. Blincoe LJ, Seay AG, Zaloshnja E, et al. *The Economic Impact of Motor Vehicle Crashes, 2000.* Washington, DC: National Highway Traffic Safety Administration; May 2002. Report DOT HS 809 446.

Making the Case for Active Living Communities

At first glance, a dearth of sidewalks may not seem like a significant public health concern. However, the disappearance of sidewalks is one of many environmental barriers to active living that transform the health of American communities in powerful ways. Evidence shows that physical activity brings substantial health benefits to people of all ages. However, much more needs to be done to create opportunities and enhance existing community structures to support physical activity.

Environments that promote active living help us all—from children who need safe routes for walking and biking to school, to busy adults who might leave cars at home if they had pathways linking them to local destinations, to older adults who can maintain functional independence longer through routine walking. In each scenario, the critical role of something as basic as sidewalks becomes clear.

Through research and demonstration programs, The Robert Wood Johnson Foundation is focusing on active living as a top-priority health concern. This emphasis has evolved primarily in response to America's overweight and obesity crisis, and the serious associated health risks.

THE PROBLEM

Overweight and obesity rates have grown dramatically in recent decades, affecting all racial, ethnic, socioeconomic, and age groups. Nearly two thirds of US adults aged 20 to 74 are overweight, and 31% are obese.[1] Even more troubling statistics relate to our nation's youth. Data from 1999 and 2000 show that more than 15% of children aged 6 to 19 years are overweight—double the proportion noted from 1976 through 1980.[2] And diseases once seen only in adults, such as type 2 diabetes, are now diagnosed in children.[3] Furthermore, overweight children are far more likely to become overweight adults who as they age face serious health problems, such as cardiovascular disease, certain cancers, osteoarthritis, depression, and other complications.

While overconsumption and poor eating habits partially account for the obesity crisis, physical inactivity is a critical contributing factor. In recent decades, changes in patterns of residence, work, transportation, and personal behavior have effectively engineered physical activity out of Americans' lives. Communities are designed to promote increased and faster vehicle flow, with little attention to safe pedestrian and bike routes. Our dependence on cars and the distance we travel in them have grown, as has the use of labor-saving devices at work and at home.[4] Collectively, these trends present major normative and environmental barriers to active lifestyles.

As a result, at least 60% of adult Americans do not meet the surgeon general's minimum targets for physical activity, defined as 30 minutes of moderate-to-vigorous activity most days of the week.[5] And regardless of body mass index, low cardiorespiratory fitness places people at greater risk of disease and death.[6] To address the epidemic of inactivity, The Robert Wood Johnson Foundation, its grantees, and various partners are working to increase physical activity levels. The long-range goal is to reverse obesity trends, particularly among youth.

POSSIBLE SOLUTIONS

The disappearance of physical activity from people's lives is a complex, entrenched problem. However, limited but growing evidence supports the effectiveness of policy, environmental, and behavioral change interventions that could improve population activity levels and related health outcomes. For instance, one study found that Japanese seniors living on walkable, tree-lined streets and close to parks outlived those with less exposure to such features—suggesting that older adults may go outdoors and get moving more when they have safe access to appealing green spaces. This holds true even when one accounts for other relevant variables, such as gender, socioeconomic status, and marital status.[7]

Across our own nation, cities and towns are reversing the cycle of underactivity and overweight. In Bolivar, Mo, citizens can talk to Mayor Charles Ealy without an appointment—if they keep pace with him on his weekly walks in city parks or along the local Rails to Trails path. Ealy's Council on Health and Fitness also hopes to connect sidewalks to create a continuous walking route through Bolivar.[8] And in Houston, which *Men's Fitness* magazine crowned the Fattest City in America for 3 years running, the mayor has launched a "Get Lean Houston!" campaign to educate residents about diet and exercise and publicize Houston's underused parks and recreation facilities.[9] These initiatives reflect strong leadership, growing recognition of the connection between physical activity and environmental design, and creativity in delivering active living opportunities.

Robert Wood Johnson Foundation grantees and others also are working to increase physical activity by exploring critical research questions, outlining policy priorities, rethinking community design issues, and encouraging people to be more active.

Active Living Research funds studies exploring how different policies and environmental characteristics affect physical activity levels. Grantees at Portland State University, for example, are testing whether people walk and bike more in neighborhoods with connected streets rather than cul-de-sacs. The idea is to provide community designers, policy officials, transportation planners, and others with evidence for creating activity-friendly communities.

Other programs apply research and policy findings to action-based strategies within communities. Active Living by Design places health at the forefront of community design by promoting best practices in planning, transportation, and architecture that encourage physical activity. It funds community-oriented partnerships of experts in public health, architecture, development, recreation, and public safety to design and apply strategies that promote active living.

Laying the groundwork for physically active communities requires engaging the talents and perspectives of experts from diverse fields. This is the focus of a leadership coalition that works to improve health by changing environments in ways that allow kids and families to be more active. The Active Living Network engages designers, planners, engineers, recreation officials, transportation experts, and public health officials in informed dialogue, research, and project implementation. Its collaborative approach highlights how participants from each field can influence a community's overall health.

Government leaders also require expertise and technical support to help communities become more active. Active Living Leadership spearheads a team of grantees—including the National Governors Association, Local Government Commission, and International City/County Management Association—to address this need. These groups provide state and local officials with best practices, planning expertise, and communications tools to help them create activity-friendly policies and places.

Communities also can turn to the Active Living Resource Center, a project of the National Center for Bicycling & Walking that supplies information and technical assistance on issues related to transportation, land-use planning, school location and design, recreation and trails, and safety.

As we work to reengineer physical activity back into the daily lives of all Americans, we must address a challenging question: If we build it, will they come? Realistically, the answer is probably not. Even with parks, trails, and greenways readily available, most people are not likely to use them regularly without compelling incentives. It is critical, then, to understand barriers to physical activity that are rooted in people's attitudes and habits in order to develop interventions that will get them moving again. Toward this end, The Robert Wood Johnson Foundation supports behavior change and social marketing efforts to complement its research- and policy-oriented grants.

In West Virginia, the Wheeling Walks health education and media campaign is shaking residents out of their sedentary ways. Remarkably, 90% of Wheeling-area residents learned of the program through advertisements, broadcast promotions, and news stories. Ultimately, it spurred a 14% net increase in the number of residents who increased their walking compared with a control community.[10] To date, nearly 2500 walkers have logged almost 29 000 miles, and they continue to pound Wheeling's sidewalks and trails.

Similar initiatives are taking hold across the country. For example, Active for Life, a national effort to increase activity among midlife and older adults, tests 2 types of physical activity programs—a structured group lifestyle program and an individually tailored program supported by telephone counseling—to determine which strategies work best for older Americans. Active for Life also collaborates with the American Association of Retired Persons on an integrated marketing and media campaign in Richmond, Va, and Madison, Wis. The campaign has 2 aims: motivating participants to make physical activity a part of daily routines and encouraging them to advocate for community design changes, such as biking and walking paths. Outcomes will be shared widely so that other communities can develop effective programs for older populations.

CONCLUSION

Through these collective efforts, The Robert Wood Johnson Foundation hopes Americans of all ages will find it logical, easy, safe, and enjoyable to get out of their cars, homes, and offices and reconnect with their communities via sidewalks and trails.

We are optimistic that, with better environmental tools in place, more Americans will make physical activity a seamless part of everyday living and maintain healthier lifestyles. The Robert Wood Johnson Foundation will continue to encourage leaders within and outside the traditional public health arena to focus on the need for active communities as a natural extension of their work. Developers, architects, transportation planners, school board officials, and government leaders alike must make physical activity a priority for the populations they serve. In essence, each group must commit to making the sidewalk an indispensable feature of American neighborhoods once more. Progress may be slow, and success is not assured. However, the tremendous health benefits to be gained through active living demand that we explore, invest in, and promote ways to reduce overweight, obesity, and persistent inactivity. ■

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References

1. Centers for Disease Control and Prevention. Prevalence of overweight and obesity among adults: United States, 1999–2000. Available at: http://www.cdc.gov/nchs/products/pubs/pubd/hestats/obese/obse99.htm. Accessed December 26, 2002.

2. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA.* 2002; 288:1728–1732.

3. Office of the Surgeon General. Overweight in children and adolescents. Available at: http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_adolescents.htm. Accessed January 22, 2003.

4. Active Living Policy and Environmental Studies Program. Call for proposals, round II. Available at: http://www.alpes.ws/content/ALPESRoundIIFinal.pdf. Accessed December 23, 2002.

5. Office of the Surgeon General. Overweight and obesity: what you can do. Available at: http://www.surgeongeneral.gov/topics/obesity/calltoaction/fact_whatcanyoudo.htm. Accessed December 26, 2002.

6. Wei M, Kampert JB, Barlow CE, et al. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *JAMA.* 1999;282:1547–1553.

7. Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *J Epidemiol Community Health.* 2002;56:913–918.

8. Watson J. Bolivar mayor starts fitness kick. *Springfield News-Leader.* January 5, 2003: B2.

9. Griffiths K. America's fattest cities 2003. *Men's Fitness.* February 2003: 70–79, 148–150. Available at: http://www.getleanhouston.com/press/press_kit.htm. Accessed January 16, 2003.

10. Wheeling walks. 2002. Available at: http://www.wheelingwalks.org/results.htm. Accessed January 30, 2003.

The Legal Perspective

The Built Environment and Its Relationship to the Public's Health: The Legal Framework

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The built environment significantly affects the public's health. This was most obvious when infectious disease was the primary public health threat during the industrial revolution; unsanitary conditions and overcrowded urban areas facilitated the spread of infection.

However, even today in the age of chronic diseases there remains an important connection between population health and the built environment. Physical spaces can expose people to toxins or pollutants and influence lifestyles that contribute to diabetes, coronary vascular disease, and asthma.

Public health advocates can help shape the design of cities and suburbs in ways that improve public health, but to do so effectively they need to understand the legal framework. This article reviews the connection between public health and the built environment and then describes the legal pathways for improving the design of our built environment. (*Am J Public Health.* 2003;93:1390–1934)

DURING THE 19TH CENTURY, the connection between public health and the built environment became increasingly apparent as hundreds of thousands of workers crowded into unsanitary, industrial cities with a resulting increase in disease and epidemics and a decrease in life expectancy.[1] In this era, dramatic improvements in public health in industrialized nations were made possible by changes in the built environment. The installation of comprehensive sewer systems, improvements in building designs to ensure that residents had light and fresh air, and the movement of residential areas away from noxious industrial facilities all brought significant improvements in health.[1] In many respects, sanitary engineers were the first urban planners in America.[2]

Industrialization not only highlighted the connection between the built environment and public health, but it also established the dominant view that population concentration and proximity between businesses and residences were unhealthy. This view was reflected in the esthetics of the City Beautiful movement[3,4] as well as in the social agenda of many in the early 20th-century housing-reform movement.[4] It is also reflected in the zoning ordinances that took hold in the 1920s. These ordinances separated neighborhoods for residential, business, and industrial uses and specified building heights, setbacks, and the density of use.[4] They were consistently justified because population deconcentration and separation of uses improved "public health, safety, morals, [and] general welfare."[5]

By the mid-20th century, the connection between public health and the built environment seemed to diminish. Infectious disease had been brought under control, and as a result the layout and planning of cities came to be viewed as a matter of esthetics or economics, but not health. Public health officials concentrated on human behaviors such as smoking and to the extent they considered the built environment, the focus was on more discrete issues such as lead paint rather than larger-scale planning issues.

Today the primary public health problems are chronic diseases rather than infectious diseases, and half of Americans live in suburban rather than urban or rural settings.[6] These changes have not eliminated the connection between public health and the built environment but suggest a sharply different focus than that of a hundred years ago. Indeed, deconcentration of populations and the separation between residential and business areas, measures urged a hundred years ago to improve health, may contribute to chronic health problems. The spread-out design of suburbs increases reliance on the automobile. This in turn contributes to air pollution, with its detrimental effects including chronic respiratory ailments, and to a sedentary lifestyle and obesity.

In contrast to the situation in the cities of the mid-19th century, today nearly all aspects of the built environment are shaped by law and governmental decisions. What can be built in what location is regulated by a complex set of local, state, and federal laws. A second significant change is that unlike the situation in the 19th and early 20th centuries, today's public health advocates have been largely absent from discussions about major planning or land-use decisions involving the built environment. Many cities and counties around the country have large planning departments or other bureaucracies that regulate land use and buildings. These frequently in-

clude urban planners, architects, lawyers, economists, transportation engineers, environmental scientists, and demographers. They rarely include public health officials. This may reflect a broader phenomenon of the increasing isolation of public health officials within government.[7] Nonetheless, public health officials can add an important voice to the decisions that shape the built environment. We later explain the relation between physical space and healthy populations, examine the legal tools to improve the built environment, and offer guidelines to help public health professionals be effective advocates in political decisionmaking.

THE RELATION BETWEEN PHYSICAL SPACE AND HEALTHY POPULATIONS

The built environment influences the public's health, particularly in relation to chronic diseases. There is good evidence to indicate that the burden of chronic disease in the population can be reduced through an active lifestyle, proper nutrition, and reduced exposure to toxic conditions.[8] However, many urban and suburban environments are not well designed to facilitate healthy behaviors or create the conditions for health. Health officials can provide information about healthy living, but if people live in poorly designed physical environments, their health will suffer.

To understand the effect of the built environment on health, it is necessary to examine the major health threats facing Americans. The leading causes of death in the United States today are heart disease, cancer, cerebrovascular diseases (including stroke), chronic lower respiratory diseases (such as asthma, bronchitis, and emphysema), and unintentional injuries.[9]

A sedentary lifestyle and poor nutrition contribute to obesity, a risk factor for some of the leading causes of mortality, including cardiovascular disease, diabetes, stroke, and some cancers.[10–12] In fact, more stroke deaths in the United States are caused by obesity and hypertension than any other behavioral risks.[11] Although the American public is largely aware of the health risks associated with obesity, the percentages of overweight or obese (overweight is defined as having a body mass index greater than or equal to 25, whereas obese is defined as a body mass index of greater than or equal to 30)[9] American adults and children are growing. In 1999–2000, 64.5% of Americans older than 20 years were overweight, and 30.5% were obese.[9] These figures are up about 8% from 1988–1994 figures. About 15% of children aged 6 to 19 years are overweight, a 4% increase from 1988–1994 data.[9]

Toxic conditions also contribute to the leading causes of morbidity and mortality, especially chronic respiratory diseases and cancer. Asthma, a chronic respiratory disease, can be triggered by environmental factors such as pollen and grass seeds and atmospheric pollutants, both indoor and outdoor.[13] Indoor pollutants are believed to be a significant cause of asthma in the inner city. It has been shown that cockroach antigens, found in the insects' feces, eggs, saliva, and shed cuticles, can trigger asthma.[14] Outdoor pollutants, such as ground-level ozone and respirable particulate matter, can also increase the incidence of asthma.[15] Automobiles and factories produce significant amounts of ground-level ozone, respirable particulates, and other pollutants. When traffic was reduced in Atlanta for the Olympic Games, peak ozone concentrations decreased 27.9% and the number of asthma emergency medical events simultaneously fell by 41.6%.[16]

Although the links between physical activity, proper nutrition, a clean environment, and health are well known, the current built environment does not promote healthy lifestyles. Many urban environments lack safe open spaces that encourage exercise and easily accessible nutritious food and promote the use of alcohol and tobacco products through outdoor advertising. A spread-out suburban design facilitates reliance on automobiles, increasing pollution and decreasing the time spent walking from place to place.

The environment is integral to encouraging physical activity.[17] Yet urban areas frequently lack adequate safe playgrounds and green spaces. The "open space" that exists may be vacant lots covered with garbage and debris, which attracts vermin and can harbor criminal activities.[18] Children may choose to play in the streets rather than in the broken glass, garbage, and used needles of the vacant lots.[18] This lack of safe places discourages a child's play and exercise. In addition, neighborhoods without green space lack a sense of community and feature increased acts of violence when compared with those that surround green space.[16]

Land-use patterns also affect the health of urban communities. Urban neighborhoods may be home to a region's most toxic sites. One area of the South Bronx section of New York City had the largest wastewater sludge pelletization plant in the Northeast (it was forced to close) and the region's largest medical waste incinerator.[19] Not coincidentally, the area has a childhood asthma rate 1000% higher than that of the rest of New York State.[19]

Urban environments may be lacking in other resources as well. Convenience stores and establishments that serve fast food may vastly outnumber grocery stores where people can purchase nutritious food. In addition, hospitals and medical care centers may close in urban places where constituents lack a strong political voice. The remaining medical providers are without sufficient resources.[20] The urban environment may also encourage risky behaviors such as smoking and drinking. Researchers have noted that tobacco and alcohol marketers have targeted urban communities.[21]

The design of suburban communities also affects the public's health. Large distances between work and home mean more space taken up by roads and an increased reliance on automobiles. This has multiple health effects. First, pollutants from automobiles increase as miles traveled increases. Increased pollution increases deaths from respiratory[22] and cardiopulmonary illnesses.[23] Second, as time spent in traffic increases, leisure time available for health-promoting activities may decrease. This leads to reduced time in which to exercise and engage in other health-promoting activities. Third, increasing hours on the road increase the opportunity for traffic accidents and deaths due to unintentional injuries.

Although suburban dwellers have higher rates of leisure exercise and suburban women have lower obesity rates than their urban and rural counterparts, better suburban design could increase opportunities for exercise.[24] Shopping areas are designed to be driven to, and walking from errand to errand is difficult. The spread-out nature of the suburb increases reliance on automobiles and may not be ideal for increasing opportunities for exercise.

The built environment affects health in a number of ways. It is not sufficient to educate people regarding healthy lifestyles; the built environment must promote, or at least allow for, engaging in healthy behaviors. Law can be used as a tool to accomplish this goal.[25]

LEGAL PATHWAYS FOR IMPROVING THE BUILT ENVIRONMENT

The law can be a potent tool in creating a built environment that is conducive to public health. Legislatures design broad policies and parameters, including processes for making decisions that affect the built environment. The decisions of legislatures are carried out and enforced by more specialized bodies such as planning boards, zoning boards, and administrative agencies. Public health practitioners can best influence decisions by intervening early in the process, when broad policies are being made about population density, land-use configurations, transportation, and other important issues.

There are 5 main legal avenues for affecting the built environment: environmental regulation to reduce toxic emissions; zoning ordinances that designate an area for a specific use and related developmental requirements; building and housing codes that set standards for structures; taxing to encourage or discourage activities or behaviors; and spending to provide resources for projects that enhance the built environment. The exact mechanisms vary by state and locality, but the general principles are similar.

Environmental Regulation

A web of federal and state laws regulates the emission of toxic substances or pollutants that degrade the environment. These measures are aimed at improving the built environment by reducing pollutants and ensuring the quality of air and water. Federal law, for example, requires US agencies to prepare an environmental impact statement before beginning a major action affecting the quality of the environment. The Environmental Protection Agency is empowered to establish air and water quality standards. This was the mechanism, for example, through which the Environmental Protection Agency prohibited the use of lead in automobile fuels, leading to improvements in children's health. State and local governments often have their own regulatory regimes for controlling the industrial release of toxic substances, as well as laws concerning storm water management, forest and stream valley protection, and septic systems.

Zoning and Related Developmental Requirements

The Supreme Court, in *Village of Euclid, Ohio v Ambler Realty Co*, long ago recognized that zoning ordinances are a proper exercise of the state's police power because they protect the health and safety of the community. Zoning laws specify within designated areas allowable uses of land and buildings and regulate building density and size. Common land-use classifications include industrial, manufacturing, agricultural, commercial, and residential. Zoning can have powerful effects on communities by separating manufacturing from residential areas but can also encourage spread-out suburban patterns where jobs, housing, and retail services are far apart, residents are entirely automobile-dependent, and walking to a destination is difficult. Indeed, large-lot zoning intended to protect open space may be a major contributor to suburban sprawl. Moreover, zoning has not always been used effectively to protect poorer and minority residential areas from potentially hazardous industries and uses. In addition to zoning, many communities impose additional requirements on some developments. For example, large residential developments may be required to provide a percentage of affordable housing units along with recreation amenities.

Building and Housing Codes

Building and housing codes influence the built environment, especially as Americans spend approximately 90% of their time indoors. These codes are designed to ensure that buildings are safe, sanitary, and efficient. Most localities adopt codes based on models developed by national organizations such as the International Code Council. Building codes require minimal safety features, such as gated enclosures around swimming pools, insect screens on windows, smoke alarms, and negotiable stairways and exits. These codes may also regulate toxic materials, including the removal of asbestos and lead pipes or paint. In fact, partly because of the abatement of lead paint in housing stock, blood lead levels in children have de-

clined dramatically.[26,27] But building codes can also be so restrictive that they discourage the renovation of existing buildings and thereby contribute to urban deterioration.

Taxing Power

Although pollution regulation, zoning, and building codes exert direct control over the design of buildings and communities, the law also affects the built environment marketplace through taxing and spending. The tax code influences the built environment through tax relief, tax burdens, and the ability to recognize and take title to abandoned property. The government can provide tax incentives to encourage construction of affordable housing and investments to renovate existing buildings or abandoned industrial sites. The government can also discourage actions that degrade the built environment by taxing them. For example, government can improve air quality by taxing gasoline and ozone-depleting chemicals to reduce their use and more accurately reflect their cost to society.

Spending Power

Closely related to the power to collect revenue is the power to spend. Governments can spend resources in ways that create or promote a healthier and safer built environment. The government, for example, can promote physical activity by locating and designing public facilities to encourage pedestrian access and including in the funding sufficient money for adequate sidewalks, bicycle paths, and streetscaping. It can acquire open space for recreation and environmental protection. For example, in 1998, New Jersey voters approved a $1 billion bond initiative to acquire 1 million acres of open space. Similarly, governments can require public health–enhancing behaviors as a condition of receiving appropriations. For example, federal transportation appropriations are linked with regions achieving specified reductions in ground-level ozone. On the other hand, government spending can also contribute to some unhealthful aspects of the built environment. Roads can be designed primarily for automobile speed, with little attention to pedestrian safety or comfort. Many state reimbursement policies for local school construction favor building new buildings over renovating old ones, and this can contribute to deterioration in existing neighborhoods and encourage sprawl.

Summary

Law influences the built environment in a variety of ways, ranging from environmental regulation, zoning, and building codes to economic incentives and disincentives. The public health community can use its voice, expertise, and influence to encourage legislatures and agencies to create and enforce laws designed to ensure the conditions for people to be healthy. The concluding section presents 7 strategies for accomplishing this goal.

PUBLIC HEALTH ADVOCACY FOR HEALTHIER PHYSICAL SPACES

With the decline in focus on sanitation and infectious disease, public health advocates have been relatively invisible in the political process that shapes the built environment. Instead, the leading voices have been those of environmentalists, the business community, land owners and developers, architects and urban planners, and civic activists seeking to protect established neighborhoods. Public health expertise is critical to the process. The following guidelines will help public health advocates become a constructive and effective voice:

1. *Get involved early in the planning process.* Critical decisions about land use and the built environment are made through a legal process. Once specific projects are proposed and presented to the public, it may be too late to have significant impact on what is built–the important ground rules are likely to have been set far in advance.
2. *Bring data to the table.* Public health scientists bring unique training in epidemiology and empirical analysis. Scientific data on the kinds of designs and land-use arrangements that encourage physical activity are lacking. Urban planners have instincts in this area, but these instincts may not be supported by sound data.
3. *Help policymakers use data more carefully.* Policymakers are particularly influenced by actions that are immediately measurable, and bureaucracies are set up to reward those who show positive short-term changes. For example, highway departments may be rewarded for reducing pedestrian accidents by making a road so inhospitable that few pedestrians venture out. Public health officials may be able to provide data and a perspective to counteract this tendency.
4. *Be a voice that is independent of the environmental and esthetic concerns.* Today, public health officials may find that they share much with the environmentalists and urban designers who promote compact, mixed-use development, but the agendas may not always be coextensive. Public health officials will be a credible and useful voice only if they maintain independence. For example, bicycle paths and sidewalks add impervious surfaces that may require felling trees or altering parkland. As a result, environmental groups that support the concept of increased walking and bicycling sometimes oppose the installation of trails and bicycle paths. Public health officials can clearly enunciate the health benefits of opportunities for safe, pleasant exercise.
5. *Promote healthy activities for children and particularly teenagers.* Childhood obesity is a growing problem, and the patterns for a healthy (or unhealthy) lifestyle are frequently set in childhood. The voices of children and teenagers are left out of the planning process. Teenagers in particular may have interests that conflict with the preferences of adults. Activities that

attract groups of teenagers can be viewed as threatening and undesirable. For example, homeowner associations may prohibit the installation of driveway basketball nets because they are unsightly and the games may get loud. Likewise, although new residential subdivisions may be required to include recreational facilities, developers rarely include facilities that would be of interest to teenagers, preferring instead "tot lots."

6. *Be a voice for underrepresented populations and minorities.* Poor, immigrant, and minority populations suffer much higher rates of chronic disease. They are also much more likely to live in substandard housing, to be exposed to environmental toxins,[28] and to be the victims of unsafe pedestrian facilities.[29] From the interstate highway program of the 1950s and 1960s that razed thousands of low-income housing units to rezoning for industrial uses, poor and minority populations have borne the brunt of some highly destructive land-use decisions.

7. *Encourage government to lead by example, not just by regulation.* Governments invest extensively in the built environment through construction and maintenance of roads, public transportation, and public buildings and facilities. These can be located and designed to encourage walking, bicycling, and other physical activity. Public health officials can be a voice to encourage comprehensive planning that considers not only the immediate purpose (e.g., Will this be a good library?), but also how the facility functions in the community to encourage healthy choices.

Public health can be an influential voice in shaping the built environment. If advocates demonstrate competence in the legal process and use their expertise effectively, physical spaces can be designed to promote healthy populations. ■

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W.C. Perdue provided research on the history and legal tools of land-use planning. L.A. Stone provided research on public health and the built environment. L.O. Gostin assisted in synthesizing the analysis. All authors helped in conceptualizing ideas and were involved in all phases of drafting and editing the article.

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References

1. Rosen G. *A History of Public Health.* Baltimore, Md: Johns Hopkins University Press; 1993:177–178, 212–213, 314–316.

2. Peterson JA. The impact of sanitary reform upon American urban planning, 1840–1890. In: Krueckeberg DA, ed. *Introduction to Planning History in the United States.* Newark, NJ: Center for Urban Policy Research; 1983:13–39.

3. Nolan J, ed. *City Planning.* New York, NY: D Appleton & Co; 1916.

4. Scott M. *American City Planning since 1890, "The Heyday of the City Beautiful."* Berkeley, Calif: University of California Press; 1971:184–187, 152–163.

5. *Village of Euclid v Ambler Realty Co.* 272 USC §365–397 (1926).

6. US Census Bureau. Population, housing units, area, and density: 2000. Available at: http://factfinder.census.gov/servlet/GCTTable?ds_name=D&geo_id=D&mt_name=DEC_2000_SF1_U_GCTPH1_US15&_lang=en. Accessed January 13, 2003.

7. Colmers JM, Fox DM. The politics of emergency health powers and the isolation of public health. *Am J Public Health.* 2003;93:397–399.

8. Institute of Medicine. *The Future of the Public's Health in the 21st Century.* Washington, DC: National Academy Press; 2002.

9. National Center for Health Statistics. Health, United States, 2002, Tables 32, 70, and 71. Available at: http://www.cdc.gov/nchs/products/pubs/pubd/hus/02tables.htm. Accessed January 10, 2003.

10. Must A, Spadano J, Coakley E, et al. The disease burden associated with overweight and obesity. *JAMA.* 1999; 282:1523–1529.

11. Hahn RA, Teutsch SM, Rothenberg RB, Marks JS. Excess deaths from nine chronic diseases in the United States, 1986. *JAMA.* 1990;264:2654–2659.

12. Mokdad AH, Ford ES, Bowman BA, et al. Prevalence of obesity, diabetes, and obesity-related risk factors, 2001. *JAMA.* 2003;289:76–79.

13. British United Provident Association. Asthma. Available at: http://hcd2.bupa.co.uk/fact_sheets/Mosby_factsheets/asthma.html. Accessed December 18, 2002.

14. Potera C. Working the bugs out of asthma. *Environ Health Perspect.* 1997; 105:1192–1194.

15. Cummins SK, Jackson RJ. The built environment and children's health. *Pediatr Clin North Am.* 2001;48:1–13. Available at: http://home/mdconsult.com/das/article/body/1/jorg=journal&source=MI&sp=11975046&s. Accessed December 2, 2002.

16. Jackson RJ, Kochtitzky C. *Creating a Healthy Environment: The Impact of the Built Environment on Public Health.* Washington, DC: Sprawl Watch Clearinghouse; 2001. Monograph Series, 1–19.

17. Goldstein B. The environment and health: a conversation with CDC chief Jeffrey Koplan; tracing the intersections between behavior and environment fascinates this top health officer. *Health Affairs.* 2002;21:179–184.

18. Lord CP. Community initiatives: environmental justice law and the challenges facing urban communities, *Virginia Environ Law J.* 1995;14:721–733.

19. Maantay J. Zoning, equity, and public health. *Am J Public Health.* 2001; 91:1033–1041.

20. Goldstein A. DC general downgrade strains hospitals; other facilities tell mayor of overwhelming patient load, rejected claims. *Washington Post.* December 10, 2002;B4.

21. Williams DR, Collins C. Racial residential segregation: a fundamental cause of racial disparities in health. *Public Health Rep.* 2001;116:404–416.

22. Kay JH. *Asphalt Nation.* New York, NY: Crown Publishers; 1997:111.

23. Peters A, Pope A III. Cardiopulmonary mortality and air pollution. *Lancet.* 2002;360:1184–1185.

24. Eberhardt MS, Ingram DD, Makuc DM, et al. *Urban and Rural Health Chartbook. Health, United States, 2001.* Hyattsville, Md: National Center for Health Statistics; 2001. Available at: http://www.cdc.gov/nchs/data/hus/hus01cht.pdf. Accessed January 13, 2003.

25. Gostin LO. *Public Health Law: Power, Duty, Restraint.* Berkeley, Calif: University of California Press and Milbank Memorial Fund; 2000.

26. Sargent JD, Dalton M, Demidenko E, et al. The association between state housing policy and lead poisoning in children. *Am J Public Health.* 1999;89: 1690–1695.

27. Ryan D, Levy B, Pollack S, et al. Protecting children from lead poisoning and building healthy communities. *Am J Public Health.* 1999;89:822–824.

28. Gelobter M. The meaning of urban environmental justice. *Fordham Urban Law J.* 1994;21:841–856.

29. Dangerous by Design: Pedestrian Safety in California. Washington, DC: Surface Transportation Policy Project; 2000.

Urban Form, Health, and the Law's Limits

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Urban form, the law, and health are undoubtedly linked. However, nonlegal factors such as 20th-century reliance on the automobile as well as associated governmental actions and private investment choices have greatly influenced urban form, especially urban sprawl.

The American system of federalism, with its traditional allocation of land-use legal authority to local governments, and resulting fragmented legal authority over causes and effects of urban sprawl, renders difficult legal efforts to reshape urban form. Legal frameworks and the dynamics and effects of urban sprawl are largely mismatched.

Still, existing legal frameworks and modest legal reforms provide means to encourage or at least allow urban forms that are more conducive to health. However, the law will not easily transform urban form and deter urban sprawl. (*Am J Public Health.* 2003;93:1395–1398)

IF A PUBLIC HEALTH EXPERT could design America's urban areas, several attractive features would be found. Residences would be within walking or bicycling distance of mass transit options, retail stores, and amenities such as restaurants. Rather than a denuded landscape, trees and green spaces would be preserved. In this idyllic setting, sidewalks would provide safety and encourage walking and associated physical fitness. Workplaces and homes would be in closer proximity, thereby reducing stress, traffic jams, and air pollution linked to long single-occupant automobile commutes. In short, the public health ideal city might look like a cross of Park Slope, Brooklyn, and London, albeit with cleaner air.

Anyone even casually examining urban form in America today, particularly in metropolitan areas that have exploded in size and population during the 20th century, finds a far less appealing picture, as Duany et al. have discussed.[1] Shopping centers have replaced villages within short distances of homes. Sidewalks are often utterly lacking. Sprawling subdivision construction frequently starts with clearing of the land before isolated residential areas replace either agricultural lands or less dense forms of suburbia. Serpentine suburban roads end in cul-de-sacs and often provide no safe access to commercial areas except by automobile on multiple-lane, pedestrian-hostile roads. Previously vital urban centers are often depleted of stable residents and businesses as malls, distant suburban housing, and sometimes better government services beckon and are made readily accessible with yet more highway construction. Abandoned, decaying, and often contaminated industrial sites referred to as *brownfields* often sit empty and deter urban reinvestment.[2] Mass transit investments lag and seldom provide a practical alternative to automobile use. The ideal and the real stand in marked contrast, especially from a public health viewpoint.

This article explores the law's role in shaping urban form, particularly pervasive sprawling patterns of development, and illuminates legal links between the law, urban form, and health. Our legal system and current array of laws surely influence urban form. However, the law is far from the most significant contributor to contemporary urban shape and, concomitantly, will not offer a miraculous cure. To discern law's responsibility and promise for urban form in America requires attention to the dynamics shaping urban areas.[3–6] Much as treating an illness requires understanding of underlying causes, no regulatory intervention will succeed without tailoring of remedial legal steps to the causative factors. The combination of market choices, technological change, and historical allocations of regulatory authority under the US federalist system make the ills associated with urban sprawl difficult to prevent or remedy. Nevertheless, legal improvements, reform, and more effective use of current legal structures could alleviate some of urban sprawl's ills, even if larger urban sprawl trends remain difficult to combat.

URBAN FORM AND COMPLEX CONTRIBUTING DYNAMICS

Before delving into the US legal system's influence on urban form, one should first acknowledge contributors to urban form not directly attributable to legal frameworks. Most significant is increased reliance on the automobile. Cities that experienced their metropolitan boom during the 19th century or earlier tend to offer significant mass transit, particularly rail, as well as urban parks and designs accommodating pedestrian traffic.[7] In the era before automobiles, parks were necessary to provide residents access to green space and trains were the primary means to provide access to and from more distant metropolitan areas. Not surprisingly, the cities viewed as most functional by new urbanists, and perhaps a public health ideal, tend to be pre-20th-century cities. Similarly, the European cities lauded by new urbanist advocates, such as James Howard Kunstler, developed much of their densely intertwined and vibrant urban fabric long before automobiles offered easy access to dispersed urban regions.[8]

In contrast, when one looks at the metropolitan areas that boomed during the latter half of the 20th century to the present, one finds radically different urban shapes and relatively pal-

try investments in parks, rail transit, and pedestrian-friendly design. Instead, highway construction became the norm, and individual reliance on the automobile replaced widespread rail investment and usage.[9] Many of urban sprawl's most pernicious attributes from a public health perspective—fragmented and widely dispersed neighborhoods; minimal planning to accommodate or encourage walking, bicycling, and mass transit; chronic air pollution; and great distances between work, retail centers, and homes—flow from an automobile-dependent culture.

However, Americans have not been dragged kicking and screaming to their suburban homes. Americans' love affair with single-family suburban homes, although criticized by many for their insularity and side effects, should not be underestimated in assessing the dynamics contributing to sprawling urban forms. Citizens continue to acquire new homes in yet-more-distant suburban enclaves, often for less money than in urban centers. Small parks and recreational areas are sometimes found in these more suburban metropolitan areas, but often not within bicycling or walking distance of residential areas. The urban exodus is at least partly attributable to racial tensions and deteriorating urban centers. Market incentives remain strong for developers to develop distant areas. Furthermore, once cities develop dispersed residential patterns and are reliant on huge retail stores and malls, they are difficult to reshape after the fact. These private market choices to rely on the automobile and single-family homes have led some critics of anti-sprawl policies to decry any legal policy shift from the status quo as akin to un-American central planning and a threat to freedom.[10]

THE LAW'S CONTRIBUTION TO URBAN FORM DYSFUNCTION

Although I acknowledge the important linkages of individual choice, the automobile and the flight to suburbia should not obscure the many ways in which the US legal system has shaped and facilitated these trends.

US Federalism

The US federalist system of governance renders difficult any efforts to combat sprawl's harms. By *federalist system,* I refer to the division of regulatory authority among local, state, and federal levels of government, with a federal government of limited power. Sprawl's dynamics and effects and historical allocations of legal authority are mismatched. The lack of a matching level of government creates predictable political–economic hurdles for citizens and public health and environmental advocates seeking to reshape urban form. Not only must laws and regulations change, but new forms of governance also may need to be created.

For instance, sprawl and its underlying dynamics tend be regional or broader in cause and effect. Federal and state agencies underwrite most highway construction but have a limited programmatic charge, generally overseeing highway construction but dealing little with associated harms and ripple effects of projects facilitating yet more sprawl. Indeed, such agencies frequently are a source of patronage projects that are undertaken with little evidence of public benefit. New highway construction does, however, create substantial immediate benefits for agency clout and budgets, for businesses linked to such infrastructure projects, and for adjacent real estate owners who suddenly hold land of great value. Government officials seldom have incentives to oppose highway construction. Furthermore, federal mortgage deductions and mortgage qualification policies for many years created a federally financed incentive for the acquisition of single-family homes. Many urban dwellers, especially renters in apartment settings, benefited from no similar federal financial inducements.

Historically, land-use planning and governance has been a local governmental duty, under broad state law authorizations. Even if a local government concluded that a metropolitan area's dysfunctions were attributable to its dispersed forms, that local government would have limited capacity to derive a legal remedy. Central city officials seek private, federal, or state investment in the urban core. They hope to deter the suffering that follows business and residential shifts to distant localities happy to attract new investment. However, lacking power over other local governments seeking new investment, central-city constituencies, environmentalists, and health advocates lack a political venue in which to focus their efforts. Intergovernmental competition for business and new development thus continues, creating yet more population dispersion, air pollution, and traffic. Local governments can, and occasionally do, cooperate on regional issues, but ongoing institutions to implement those cooperative goals remain scarce.[11]

Local Governmental Planning Traditions and New Urbanist Barriers

Many of the dysfunctional urban microenvironment attributes—lack of sidewalks, dead-end neighborhoods, and great distances between residences and recreational and commercial amenities—result not from the US federalist form of government but from lack of local political will and land use traditions of separating different land uses. Early "Euclidean" zoning had its roots in efforts to separate noxious land uses and residences, thereby protecting citizens from health and property devaluation threats posed by potentially adjacent factories and commerce.[12,13] Overly rigid adherence to these zoning separations by use, however, can preclude mixed-use neighborhoods that would foster more health-conducive modes of development and transportation. Abandoning such protections and separations is politically dif-

ficult once an area has been developed. Suburban home residents have a strong property value stake in fighting new nearby adjacent commercial and transportation uses. Furthermore, once real estate investments have been made, substantial governmental changes in permitted land uses can give rise to constitutional "takings" claims seeking governmental compensation.[14,15]

Still, in most newly developing neighborhoods, little other than tradition requires rigid use separations.[16] Even where Euclidean separations by use remain the norm, land use law is changeable, offering numerous means to escape initially applicable constraints. In addition, local governments retain power to require developers to preserve green space and tree cover and provide sidewalks. In most jurisdictions, newly developed areas can allow or even mandate new urbanist land-use forms. Lack of political will to insist on them and interest group pressure against them typically explain the lack of such amenities. It remains an open question if, when given a choice, home purchasers and developers of commercial and residential areas will choose to invest in mixed-use forms over yet more single-family automobile-dependent homes.

THE LAW'S PROMISE IN ALLEVIATING URBAN FORM HEALTH ILLS

In addition to local and state land use traditions and opportunities discussed earlier, current laws provide several additional levers for improving urban form. Additional innovative legal reforms could further discourage sprawl or alleviate associated harms.

Current Laws and Improved Urban Form

Probably the foremost federal law creating disincentives for unbridled sprawl is the federal Clean Air Act.[17] The Clean Air Act requires federal setting of National Ambient Air Quality Standards to protect public health "with an adequate margin of safety" for pervasive pollutants such as ground-level ozone, particulates, and carbon monoxide. This law creates incentives for urban designs that are less automobile-dependent by obligating state and local governments to derive State Implementation Plans to attain the National Ambient Air Quality Standards.[18] For the many nonattainment areas for ozone, for example, strategies to reduce single-passenger automobile use, traffic congestion, and multiple short trips a day would reduce automobiles' substantial contribution to ozone pollution. Local measures to encourage such behavioral changes, if able to create quantifiable air quality improvements, could avoid the imposition of more costly pollution control methods. The main statutory hammer—cutoffs of federal highway funds for areas failing to address their nonattainment problems—directly links one of the chief contributors to sprawl to clean air woes.

Most major federal or state infrastructure projects, such as new highway construction, will potentially require analysis of environmental impacts under the National Environmental Policy Act[19] or analogous state and local laws. As public health experts create a body of data linking health harms to urban sprawl, pedestrian-unfriendly design, destruction of green spaces, and lack of sidewalks, such information can be plowed into the environmental impact statement analysis process. This information, combined with analysis of other effects on the human environment, might lead more informed government officials to embrace less harmful alternatives and mitigation measures. The National Environmental Policy Act does not mandate the adoption of mitigation measures or least harmful alternatives. However, some state and local analogues do mandate the implementation of measures to reduce environmental harms.

Relatedly, recent changes in federal transportation funding evident in the Transportation Equity Act-21 law and its predecessors now allow more flexible uses of dollars previously dedicated to highway building.[20] Because of newly required more open local and state political planning processes, federal monetary incentives for alternative transportation modes are available. Linked provisions in transportation laws and the Clean Air Act create enhanced incentives for local governments to come up with measures to reduce automobile pollution.[21] Long-existing provisions in federal transportation laws prohibit the release of federal money for projects that would destroy green spaces such as parks where a "feasible and prudent alternative" exists.

An executive order signed by President Clinton requires federal agencies to avoid taking actions that would exacerbate environmental discomforts disproportionately borne by poor and minority communities.[22] Although the order is not judicially enforceable, advocates can use it to prod reluctant federal agencies to consider broader repercussions of actions such as funding or approving transportation projects that might exacerbate injustice by harming urban centers and contributing to sprawl.

Legal Reforms

Arrayed against the powerful forces that have created the contemporary sprawlscape, current legal frameworks offer reason only for moderate optimism. A number of reform measures, some under way and some only occasionally found, could further encourage urban forms more conducive to health. As discussed earlier, modifying state and local laws to permit mixed-use development is an essential first step all jurisdictions should consider. Other ideas follow.

State creation of regional governing entities that could oversee transportation and infrastructure projects with a regional impact are a necessary step that several states have adopted to deal with transporta-

tion and dispersed growth dysfunctions. These entities are often created as "public authorities" with minimal democratic accountability but can offer a governing apparatus that better matches and addresses the dynamics and harms associated with sprawl.[23]

The Portland, Ore, metropolitan area, for example, has created a regional governance entity to oversee growth boundary constraints designed to reduce urban dispersion.[24] Growth constraints, however, pose a risk of distributional harms if without compensation they abruptly deny some landowners the ability to sell or develop their land consistent with area trends. Furthermore, such constraints pose a risk of serving as cover for exclusionary practices that may price poorer residents out of a region. The creation of authorities to assess and avoid exacerbating sprawl harms remains an important reform, but these blunter growth constraints can engender fierce opposition if not tailored to avoid harsh or exclusionary results.

Federal transportation dollars have slowly shifted from a highway-funding obsession to allowing increased use of federal dollars for nonhighway transportation enhancements. Even more targeted conditional spending incentives for green-space preservation, the provision of greenways or rail-to-trail paths, or the provision of viable mass transit alternatives could alleviate the tendency to build more highways. Greater monetary incentives for the creation of nodal developments built close to mass transit facilities might also shift incentives in a publicly beneficial manner. The imposition of commuting taxes either as part of mass transit fares to and from central urban areas, or through modern automobile tollbooth scanning technology, could also discourage distant commuters and force them to perceive some of the costs of sprawl. Such measures could also backfire, however, if they created even more incentives for suburban business parks and abandonment of urban centers.

Federal hazardous waste law recently was amended to reduce liability fears associated with new investments in brownfields sites, but federal subsidies to encourage brownfields reinvestment remain paltry.[25] Given the beneficial ripple effect of brownfields revitalization, greater subsidization, coupled with private sector matches to ensure that a project is actually prudent, would be a valuable further legal innovation.

Although taxes to discourage environmentally harmful measures are many economists' favorite strategy, they are among the least utilized of regulatory strategies in environmental law.[22] Still, local governments seeking to deter land clearing before subdivision development should consider land use law reforms that would impose a tax on the destruction of significant trees and require compensatory planting. In most jurisdictions, tree cuts associated with development are subject to few regulatory constraints.

CONCLUSION

Because of our fragmented federalism and associated layers of law, legal reform is unlikely to cause a radical change in urban forms that lead to health harms. The law can, however, change incentives and deter egregious and often unnecessarily harmful practices. As environmental activists and champions of city life have found before, public health advocates must acknowledge that regional growth trends and market choices are influenced but not controlled by legal frameworks. New urbanism advocates have sought to explain the benefits of urban environments that encourage walking and mixed uses in close proximity. Health advocates illuminating the urban form–health linkages can perhaps similarly influence lawmakers and citizens to think twice before supporting yet more highway building or distant subdivisions. Such legal and political battles, however, will need to be pursued at the local, regional, state, and federal levels of government. ■

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References

1. Duany A, Plater-Zyberk E, Speck J. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream.* New York: North Point Press; 2000.

2. Michael Gerrard, ed. *Brownfields Law & Practice.* New York, NY: Lexis Publishing; 2002.

3. Buzbee W.W. Smart growth micro-incentives and the tree-cut tax case. *Georgia State Law Rev.* 2001;17:999–1012.

4. Buzbee W.W. Sprawl's dynamics: a comparative institutional analysis critique. *Wake Forest Law Rev.* 2000;35:509–537.

5. Buzbee W.W. Sprawl's political-economy and the case for a metropolitan green space initiative. *Urban Lawyer.* 2000;32:367–390.

6. Buzbee W.W. Urban sprawl, federalism, and the problem of institutional complexity. *Fordham Law Rev.* 1999;68: 57–136.

7. Foglesong RE. *Planning the Capitalist City: The Colonial Era to the 1920s.* Princeton, NJ: Princeton University Press; 1986.

8. Kunstler JH. *The City in Mind: Notes on the Urban Condition.* New York, NY: The Free Press; 2001.

9. Kay JH. *Asphalt Nation: How the Automobile Took Over America and How We Can Take It Back.* Berkeley, Calif: University of California Press; 1997.

10. Bolick C. Subverting the American dream: government dictated "smart growth" is unwise and unconstitutional. *U Pennsylvania Law Rev.* 2000;148: 859–872.

11. Gillette CP. Regionalization and interlocal bargains. *NYU Law Rev.* 2001; 76:190-271.

12. Ellickson RC, Been VL. *Land Use Controls.* 2nd ed. New York, NY: Aspen Law & Business; 2000:85–107.

13. Karkkainen BC. Zoning: a reply to the critics. *J Land Use Environmental Law.* 1994;10:45–89.

14. Haar CM, Wolf MA. Euclid lives: the survival of progressive jurisprudence. *Harvard Law Rev.* 2002;115:2158-2203.

15. Wolf MA. Fruits of the "impenetrable jungle": navigating the boundary between land-use planning and environmental law. *J Urban Contemporary Law.* 1996;50:5–93.

16. Freilich RH. *From Sprawl to Smart Growth.* Chicago, Ill: The American Bar Association; 1999.

17. 42 USC § 7401–7671 (1995 and supp. 2003).

18. 42 USC § 7410 (1995 and supp. 2003).

19. 42 USC § 4321–4370f (1995 and supp. 2003).

20. Transportation Equity Act for the 21st Century, Public L No. 105–178, 112 Stat 107 (1998).

21. 23 USC §§109(j), 134(l) (1995 and Supp 2003).

22. Executive Order 12 898, 59 *Federal Register* 7629 (1994).

23. Gillette CP, Baker LA. *Local Government Law.* 2nd ed. New York, NY: Aspen Law & Business; 1999:639–643, 803–816.

24. Nelson AC, Duncan JB. *Growth Management Principles and Practices.* Chicago, Ill: Planners Press, American Planning Association; 1995.

25. Keohane NO, Revesz RL, Stavins RN. The choice of regulatory instruments in environmental policy. *Harvard Environmental Law Rev.* 1998;22:313–367.

Local Ordinances That Promote Physical Activity: A Survey of Municipal Policies

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In this Utah-based study, we sought to identify the types of municipal employees responsible for physical activity policies, identify municipal ordinances that may influence physical activity, and determine local governments' intentions to implement policies.

In 2001, we mailed a survey to all of the state's municipalities with the goal of measuring 6 physical activity domains: sidewalks, bicycle lanes, shared-use paths, work sites, greenways, and recreational facilities. Data from 74 municipalities revealed that planners made up a small proportion of municipal staff. Relative to cities experiencing slow or medium growth, high growth cities reported more ordinances encouraging physical activity.

Physical activity policies can be monitored across municipalities. Moreover, evidence-based public health practice provides direction for limited staff and funding resources. (*Am J Public Health.* 2003;93:1399–1403)

REGULAR PHYSICAL ACTIVITY is associated with decreased risks of heart disease, cancer, and diabetes, which are leading causes of disability and death in the United States.[1] Recently the Task Force on Community Preventive Services, which conducts evidence-based reviews of the state of public health, "strongly recommended" both the creation of areas for physical activity and the enhancement of access to such areas.[2] This recommendation was based on a growing body of research on how physical activity levels are influenced by policy and environmental conditions.[3–5] Commensurate with this recommendation, state and local agencies are being encouraged by federal and nongovernmental organizations to use policy interventions to address the public health problem of physical inactivity.[6–8]

The measurement of policies related to physical activity is a new area of research, but in recent years several authors have set forth conceptual groundwork that should facilitate future investigations.[9] To date, the literature in this area has focused primarily on personal and environmental correlates of physical activity.[3,5,9–15] Although important, there is a paucity of literature examining the correlates of effective policy interventions addressing physical activity behaviors.

Although "policy as intervention" has been advocated by the Centers for Disease Control and Prevention (CDC) and others for some time,[8,16–18] little progress has been made regarding how to determine which policies exist or even what kinds of policies are effective. Despite this situation, federal grants are encouraging states to implement policy-based interventions, as exemplified by CDC's recent program announcement seeking the establishment of state-led programs in nutrition and physical activity designed to prevent obesity and related chronic diseases.[19]

Available data suggest that such characteristics of our communities as proximity of facilities, street design, density of housing, public transit, and existence of pedestrian and bicycle facilities can play an important role in promoting physical activity.[20] Areas with favorable conditions in regard to these characteristics have been termed "active community environments" (ACEs).[21] The presence of ACEs can be measured as a community-level indicator[22]; however, such indicators must be operationalized (e.g., ordinances for bike lanes).

To support state initiatives in evidence-based public health practice,[23] we detail in this article an effort to collect and characterize existing policies on ACEs in the state of Utah. We analyzed ACE policies in that state to establish a baseline that can be used to formulate objectives as part of an intervention designed to increase physical activity. Our goal was to examine 3 policy-related issues at the local level: (1) What kinds of municipal employees are responsible for planning ACEs? (2) How prevalent are policies on ACEs? and (3) What are local municipalities' intentions in terms of implementing policies? Our results can be used to further evidence-based practice through program planning and evaluation that address

policy interventions designed to promote ACEs and enhance appropriate use of limited resources within local governments.

METHODS

Instrument

At the time of this study, we were unaware of any instrument used for surveying municipalities regarding their ordinances, and thus we constructed our own (a copy of the instrument is available from the authors upon request). To ensure measurement validity, we followed the framework set forth by DeVellis[24] in developing the instrument. This framework includes the following components: determining clearly what to measure, generating an item pool, determining the measurement format, having the initial items reviewed by context experts, administering items to a sample of respondents, evaluating the responses to each item, and optimizing the length of the instrument. This process took nearly a year to complete.

We developed community-level indicators identified by the CDC[9] to measure the existence of ordinances related to 6 domains: sidewalks, bicycle lanes, shared-use paths, greenways, recreational facilities (neighborhood, school, and community parks and park and connector trails), and work sites (new commercial buildings only). The instrument includes a total of 15 items within these 6 sections.

In the case of 4 domains (sidewalks, bike lanes, greenways, recreational facilities), respondents are asked about ordinances for new, redeveloped, and mixed-use communities. Items involve 3 possible responses: "We have an ordinance," "We intend to have an ordinance within one year," and "We do not have an ordinance." The section on work sites deals with ordinances requiring new commercial buildings and site plans to incorporate amenities that encourage physical activity and bike and pedestrian commuter traffic.

The section on shared-use paths (corridors of travel for recreation or transportation within a park, natural environment, or designated corridor that is not classified as, or served by, a highway, road, or street[25]) includes a question about ordinances for building such paths, as well as an item focusing on the existence of master plans containing language addressing easements for the development of paths. Possible responses for the latter item are as follows: "We have a policy in our master plan," "We do not have a policy in our master plan," "We intend to have a policy in our master plan within a year," and "We do not have a master plan." In general, master plans formally state a city's development and redevelopment policies, setting forth a framework of principles, standards, policies, and programs that guide decisions affecting land use management.[26]

Collection of Ordinance Data

The administrative duty to create, implement, and enforce policies affecting communities falls under municipal governments. For this study, we defined *municipality* as an incorporated city or town, and we defined *policy* as a specific local ordinance passed by a municipality. We defined policies on ACEs as ordinances enacted to establish any of the domains mentioned earlier (i.e., sidewalks, bicycle lanes, shared-use paths, recreational facilities, greenways, and work site facilities).

We gathered contact information on local government officials from the Utah League of Cities and Towns, which provided us with a published directory of such officials.[27] To identify the preferred respondents within the various cities, we developed a hierarchical protocol according to job title, with city planners or planning and zoning administrators most preferred by us because city planning is one of their main functions. The prevalence of actual respondents by job title (ranked in terms of preference rating) is shown in Table 1, as is the percentage of these city officials within the population of municipal employees who have planning responsibilities.

TABLE 1—City Officials Ranked by Preference as Survey Subjects, With Percentage of Municipal Planning Staff Represented by Title and Percentage of Survey Respondents

Rank	City Official	Percentage of Population	Percentage of Respondents
1	City planner or planning/zoning administrator	17.1	26.7
2	City manager	18.7	20.0
3	City administrator	9.4	17.3
4	City recorder	14.5	13.3
5	Parks and recreation manager	3.2	7.9
6	Mayor	1.8	5.3
7	Town clerk	33.1	2.6
8	Various	2.2	6.6

In September 2001, surveys were mailed to the preferred respondents within all 236 cities in Utah; the officials contacted were asked to return the surveys within 2 weeks. Cities that responded were eligible for one of a pair of $500 incentive awards. A cover letter was also included from Utah's governor that encouraged municipalities to complete the survey. A second mailing (to nonrespondents only) was conducted 2 weeks later. Follow-up calls were made to ensure similar response rates between cities experiencing slow growth, those experiencing medium growth, and those experiencing high growth (as described subsequently). Our final survey response rate was 48.3% (n=114 cities).

Data Analyses

Utah's cities were classified into 3 categories according to population: (1) 100 000 or more (n=3), (2) 1000 to 99 999 (n=74), and (3) less than 1000 (n=37). Only the second category of cities was

included in the present analyses, because these cities represent local health districts' greatest return on investment in regard to staff time, money, and resources. The state's 3 largest cities have an established infrastructure to address urban sprawl,[27,28] and cities with fewer than 1000 residents are too small to invest their limited public health resources on ACE initiatives. Moreover, they represent a very small percentage of Utah's population (2.3%).[28]

The 74 cities selected for analysis were stratified into tertiles—"slow growth" (n=23), "medium growth" (n=26), and "high growth" (n=26)—based on their projected population growth over the next 30 years. The governor's planning and budget office has generated projections for this period using data on economic growth and decline, births, deaths, and movement of people into and out of a given area.[28] Slow growth, medium growth, and high growth classifications were determined according to cities' projected annual average rates of change. Cities with average rates of change of 0% to 1.3% were classified as slow growth cities, those with average rates of 1.4% to 2.6% were classified as medium growth cities, and those with average rates of 2.7% to 9.1% were classified as high growth cities.[28]

RESULTS

As can be seen in Table 1, individuals responsible for planning (city planners and planning and zoning administrators) made up 26.7% of our respondents; city managers and administrators, 37.3%; city recorders, 13.3%; and parks and recreation managers, 7.9%. Table 1 also displays the difference between the distribution of the population and the distribution of our respondents. To further check for response bias, we examined respondents according to city population and found that the respondent distribution matched the population distribution with the exception of cities with fewer than 1000 residents. Among such cities, the respondent distribution represented 32.5% of the state, while the population distribution represented 45.1%.

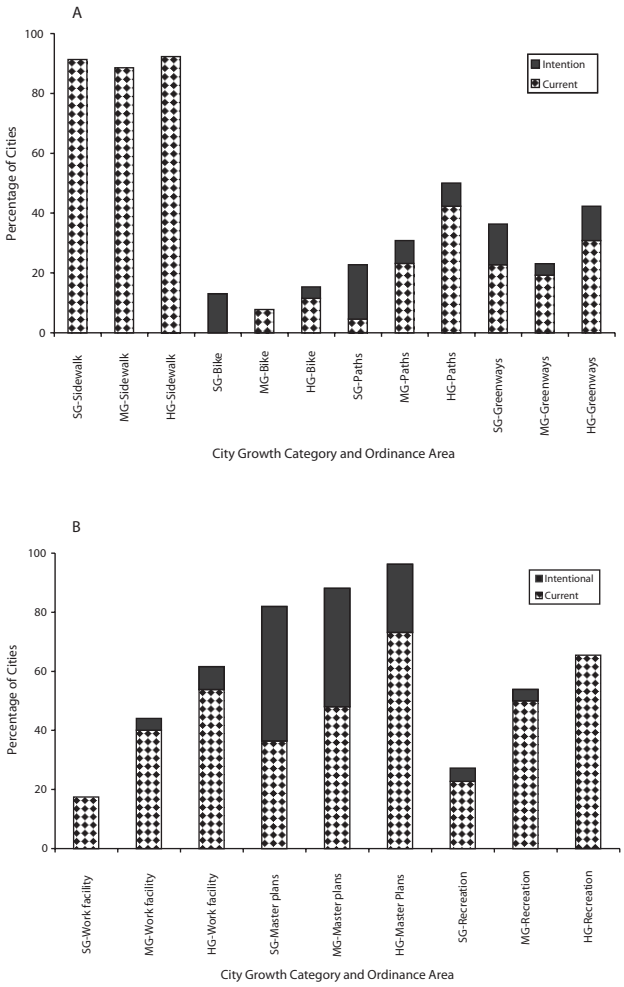

FIGURE 1—Percentages of slow (SG), medium (MG), and high (HG) growth cities with current and intended ordinances for pedestrian and bike use (A) and for physical activity infrastructure (B).

We compared slow growth, medium growth, and high growth cities in regard to 3 policy outcomes (Figure 1): (1) overall reported prevalence of ordinances for each of the ACE indicators, (2) percentage of cities intending to implement a new ACE ordinance within 1 year, and (3) actual prevalence of ACE ordinances implemented in instances in which municipalities reported an intention to implement an ordinance (i.e., actual prevalence plus prevalence of intention). With the exception of sidewalk ordinances, high growth cities were more likely to report having an ordinance in place than were medium growth and slow growth cities (Figure 1). The reported prevalence of ordinances also increased commensurate with projected annual average rate of change. In contrast, in the case of bike lanes, shared-use paths, greenways, and recreational facilities, slow growth cities were more likely to report an intention to have an ordinance in place within 1 year if one did not exist.

DISCUSSION

The goals of this study were to further evidence-based practice through program planning and evaluation addressing policy interventions designed to promote ACEs and to enhance appropriate use of limited resources within local governments. Consistent with application of the social ecological model, which describes interactions between interpersonal and intrapersonal attributes,[29] toward physical activity interventions, agencies

should be encouraged to implement policy interventions.[6,8,30] Because there is a dearth of information supporting the implementation of such interventions, we sought to examine 3 policy-related issues at the local level: the kinds of municipal employees responsible for planning ACEs, prevalence rates of such policies, and cities' intentions to implement policies.

If changes are to occur in ACE-related policies, effective networks must be formed between professionals at the state and local levels.[5,6,17,30–33] Although our respondents may not have been those who have final decisions regarding policy implementation, our results indicate ways in which to implement recent calls for transdisciplinary collaboration. We found, from our database of local government officials, that some small cities had simple staff structures for planning that involved a town clerk and a mayor. The planning structure in the large cities involved more staff, such as city administrators, city managers, city recorders, city planners, zoning administrators, parks and recreation directors, planning commissioners, and directors of community and economic development. Practitioners and evaluators will need to identify the organizational structures existing within their region.

State and local planning helps to ensure the effective allocation of limited municipal resources. In attempting to provide guidelines for resource allocation, we identified the projected growth rates of cities and stratified them according to these rates. Descriptive statistics revealed an apparent relationship between growth rates of cities and implementation of ACE ordinances. Moreover, the data collected provide a baseline of the prevalence of ACE ordinances in Utah. We used these data to provide planning objectives for the Utah Cardiovascular Health Plan, which includes goals and objectives that provide guidance for state and local partners addressing cardiovascular disease prevention.

For example, in our preliminary analysis, we stratified cities into slow growth and high growth cities. Thirty-four percent of cities falling under our high growth category reported having ordinances for shared-use paths, and another 16% reported an intention to implement these types of ordinances within 1 year. Using these data, we outlined a specific planning objective for the Utah Cardiovascular Health Plan to increase the prevalence of multi-use path ordinances from 34% to 50% among these high growth cities through several specific policy intervention strategies.

These goals would change slightly if we focused on the top tertile of the cities described in this article as experiencing high growth. Under these conditions, the goal would be to increase the prevalence of ordinances in high growth cities from a base of 42% to 50%. Results from analyses in which cities were classified into tertiles reveal that 73% of high growth cities currently incorporate shared-use paths in their master plans, and 23% intend to include language for shared-use paths in their plans. Thus, there is the potential to move this 73% baseline prevalence rate to 96%.

Limitations

Several limitations should be considered when interpreting our data. One limitation relates to respondent variability. We found considerable variation in types of respondents, and we are uncertain as to how this variability affected the validity of our survey. Although the alpha reliability coefficient[34] for our instrument was moderately high (0.71), follow-up test–retest reliability analyses are recommended to address this limitation.

A second limitation relates to the quality of the implementation of the ordinances and the specificity of those ordinances. The possibility that policies existed but had not been implemented must be considered.[30] An associated survey attempted to validate the existence of the environmental infrastructure, but respondents could not accurately quantify the existence of these types of environmental indicators (e.g., linear distance of bicycle lanes and sidewalks). The reason, in part, was that municipalities have not traditionally maintained accurate records of infrastructure. With the advent of geographic information systems, efforts are under way to address this limitation.

A related concern is the type of ordinance that exists. Although we specifically asked whether ordinances existed for the "building of" sidewalks, bike lanes, shared-use paths, greenways, and recreational facilities, the specificity of these ordinances is unknown at this point. Further descriptive analyses in which actual ordinances are examined and facilities are identified through current evaluation and application of auditing methods will be necessary to discern this information.

Implications

According to emerging research and recommendations, providing more access to areas conducive to physical activity is an important policy intervention.[2] Although recent research has provided convincing arguments for public health practitioners, there is a dearth of evidence-based public health practice in the area of ACEs. A recent report, *Policy and Environmental Change: New Directions for Public Health*,[6] encouraged public health professionals and organizations to address policy and environmental changes by providing data, convening interested parties, conducting needs assessments and evaluations, educating the public, and advocating for specific policy and environmental change strategies.

Our study provides information that can help public health practitioners and their partners make decisions about where their efforts may be most successful and offers insight into the particular strategies that should be used. Our results indicate that states can collect information related to the prevalence of policies related to ACEs. Such data,

which can be collected at low cost, can be used to develop objectives for community-level physical activity initiatives.[35] ■

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Contributors

J.J. Librett designed the study and the instrument, collected and analyzed the data, and wrote the article. M.M. Yore contributed to analyses of the data and to the writing of the article. T.L. Schmid provided expertise in policy and environmental correlates of physical activity and contributed to the development of the instrument and the writing of the article.

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References

1. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, Ga: Centers for Disease Control and Prevention; 1996.

2. Kahn EB, Heath GW, Powell KE, Stone EJ, Brownson RC. Increasing physical activity: a report on recommendations of the Task Force on Community Preventive Services. *MMWR Morb Mortal Wkly Rep.* 2001;50(RR-18): 1–14.

3. Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *Am J Prev Med.* 2002;23(suppl 2):5–14.

4. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med.* 1998;15:379–397.

5. Sallis JF, Kraft K, Linton LS. How the environment shapes physical activity: a transdisciplinary research agenda. *Am J Prev Med.* 2002;22:208.

6. Association of State and Territorial Directors of Health Promotion and Public Health Education, Centers for Disease Control and Prevention. *Policy and Environmental Change: New Directions for Public Health.* Santa Cruz, Calif: ToucanEd; 2001.

7. King AC, Jeffery RW, Fridinger F, et al. Environmental and policy approaches to cardiovascular disease prevention through physical activity: issues and opportunities. *Health Educ Q.* 1995; 22:499–511.

8. Schmid TL, Pratt M, Howze E. Policy as intervention: environmental and policy approaches to the prevention of cardiovascular disease. *Am J Public Health.* 1995;85:1207–1211.

9. Baker EA, Brennan LK, Brownson RC, Housemann RA. Measuring the determinants of physical activity in the community: current and future directions. *Res Q Exerc Sport.* 2000;71: 146–158.

10. Masse LC, Dassa C, Gauvin L, Giles-Corti B, Motl R. Emerging measurement and statistical methods in physical activity research. *Am J Prev Med.* 2002;23(suppl 2):44–55.

11. Brownson RC, Baker EA, Housemann RA, Brennan LK, Bacak SJ. Environmental and policy determinants of physical activity in the United States. *Am J Public Health.* 2001;91: 1995–2003.

12. Brownson RC, Eyler AA, King AC, Brown DR, Shyu YL, Sallis JF. Patterns and correlates of physical activity among US women 40 years and older. *Am J Public Health.* 2000;90:264–270.

13. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med.* 2002; 22(suppl 2):188–199.

14. Lewis BA, Marcus BH, Pate RR, Dunn AL. Psychosocial mediators of physical activity behavior among adults and children. *Am J Prev Med.* 2002; 23(suppl 2):26–35.

15. Miller YD, Trost SG, Brown WJ. Mediators of physical activity behavior change among women with young children. *Am J Prev Med.* 2002;23(suppl 2): 98–103.

16. McGinnis MJ, Williams-Russo P, Knickman JR. The case for more active policy attention to health promotion. *Health Aff.* 2002;21:78–93.

17. Rutten A, von Lengerke T, Abel T, et al. Policy, competence and participation: empirical evidence for a multilevel health promotion model. *Health Promotion Int.* 2000;15:35–47.

18. Stahl T, Rutten A, Nutbeam D, Kannas L. The importance of policy orientation and environment on physical activity participation—a comparative analysis between Eastern Germany, Western Germany and Finland. *Health Promotion Int.* 2002;17: 235–246.

19. Chronic disease prevention and health promotion programs: program announcement 03022. *Federal Register.* January 23, 2003:3325–3359.

20. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002;23(suppl 2):64–73.

21. Centers for Disease Control and Prevention. What are active community environments? Available at: http://www.cdc.gov/nccdphp/dnpa/aces.htm. Accessed March 31, 2003.

22. Cheadle A, Sterling TD, Schmid TL, Fawcett SB. Promising community-level indicators for evaluating cardiovascular health-promotion programs. *Health Educ Res.* 2000;15: 109–116.

23. Brownson RC, Gurney JG, Land GH. Evidence-based decision making in public health. *J Public Health Manage Pract.* 1999;5(5):86–97.

24. DeVellis RF. *Scale Development Theory and Applications: Applied Social Research Methods Series, Volume 26.* Newbury Park, Calif: Sage Publications; 1991.

25. American Association of State Highway and Transportation Officials. Guide for the development of bicycle facilities. Available at: http://www.safety.fhwa.dot.gov/fourthlevel/pdf/b_aashtobik.pdf. Accessed March 31, 2003.

26. City of Santa Clara. General plan: City of Santa Clara, California 1990–2005. Available at: http://www.cho.ci.santa-clara.ca.us/40727.html. Accessed March 31, 2003.

27. *2001 Local Government Officials Directory.* Salt Lake City, Utah: Utah League of Cities and Towns; 2001.

28. State of Utah, Governor's Office of Planning and Budget. Demographic and economic analyses: projections. Available at: http://www.governor.state.ut.us/dea/Projections/projections.html. Accessed March 31, 2003.

29. Sallis JF, Hovell M. Determinants of exercise behavior. *Exerc Sport Sci Rev.* 1990;18:307–330.

30. Buchner D, Miles R. Seeking a contemporary understanding of factors that influence physical activity. *Am J Prev Med.* 2002;23:3–4.

31. Duhl L. Health and greening the city: relation of urban planning and health. *J Epidemiol Community Health.* 2002;56:897.

32. King AC, Bauman A, Abrams DB. Forging transdisciplinary bridges to meet the physical inactivity challenge in the 21st century. *Am J Prev Med.* 2002; 23:104–106.

33. King AC, Stokols D, Talen E, Brassington GS, Killingsworth R. Theoretical approaches to the promotion of physical activity: forging a transdisciplinary paradigm. *Am J Prev Med.* 2002; 23(suppl 2):15–25.

34. Cronbach LJ. Coefficient alpha and the internal structure of tests. *Psychometrica.* 1951;16:297–334.

35. Brownson RC, Koffman D, Novotny T, Huges R, Erikson M. Environmental and policy interventions to control tobacco use and prevent cardiovascular disease. *Health Educ Q.* 1995;22:478–498.

Land Use Planning and the Control of Alcohol, Tobacco, Firearms, and Fast Food Restaurants

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We desired to understand how legal tools protect public health by regulating the location and density of alcohol, tobacco, firearms, and fast food retail outlets. We reviewed the literature to determine how land use regulations can function as control tools for public health advocates.

We found that land use regulations are a public health advocacy tool that has been successfully used to lessen the negative effects of alcohol retail outlets in neighborhoods. More research is needed to determine whether such regulations are successful in reducing the negative effects of other retail outlets on community health. (*Am J Public Health.* 2003; 93:1404–1408)

SINCE THE FIELD OF LAND USE planning and zoning originally developed in response to public health needs, there is a close intellectual and practical fit between land use goals and sound public health practice.[1] There is both substantial public health experience in and a strong legal basis for using local zoning and land use powers to achieve the public health goal of limiting the availability of consumer products proven to be harmful to health. In this article, we review the history and importance of local government use of its police power to protect public health, describe more recent invocations of police power to limit the availability of alcoholic beverages, and discuss the prospects for using these policy tools to improve public health by limiting the availability of tobacco, firearms, and nutritionally deficient foods.

POLICE POWERS

"Police power" is the inherent authority of the state (and, through delegation, local governments) to enact laws and promulgate regulations to protect, preserve, and promote the health, safety, morals, and general welfare of the people.[2] To achieve these communal benefits, the state retains the power to restrict, within federal and state constitutional limits, private interests: personal interests in autonomy, privacy, association, and liberty as well as economic interests in freedom to contract and uses of property.[2,3]

For more than a century, a government's police power has been used to justify regulating the use of land.[4] Courts have upheld the delegation of these broad powers to state and local governments on the basis of, first, the Tenth Amendment to the US Constitution, which delegates police power to the states, and, second, state constitutions, which typically delegate police powers to local governments (see, for example, Article 11 of the California Constitution).[5] Police power is broad in scope and elastic in nature, expanding to meet the changing needs of modern life.[6–8]

Subject to federal and state constitutional limits, an ordinance promulgated by a state or local government is legitimate so long as the use of police power has a rational relationship to a legitimate state purpose such as protection of the public's health, morals, safety, or general welfare.[8] Governments may find the rational basis for their ordinances in scientific studies or other types of less rigorous data or information that arguably support a legislative body's conclusion that a regulation is justified. Epidemiological reports and public health data are strong grounds upon which to base government policies or local ordinances. Because government agencies are provided broad discretion in determining which policies or ordinances are needed to protect the health, safety, welfare, and morals of their community, the ordinances will be upheld in court unless they are arbitrary, capricious, or entirely lacking in evidentiary support.[9–11]

LAND USE CONTROLS

Local governments use police powers to restrict a private property right so as to avoid harm to the public.[12] A primary way that police powers are expressed is through city planning and public health departments using their respective powers to further the public good. In fact, the modern disciplines of public health and city planning developed from common roots with similar objectives, strategies, and standards.[1]

During the 19th century, land use planning emerged as a mechanism designed to address 2 endemic public health problems: tuberculosis and cholera. The spread of disease was associated with pervasive overcrowding, a lack of sanitation, poor hygiene, insufficient water supply, insufficient fresh air, limited opportunity for outdoor recreation, and long working hours in the factories and mills.[13] Reformers, most notably Edwin Chadwick, were the driving force behind the sanitary laws that formed the basis of both city planning and public health practice. In 1843 in England, these innovative laws culminated in the first comprehensive public health act.[13] While this act did not include zoning as a specific regulatory function of government, it did call for the mapping of sewage facilities to ensure that new dwellings were equipped with drains and lavatories.[13]

New York City was the forerunner of modern zoning; in the 1890s, it established design standards to ensure that light, air,

water, and sewage were available to residents of tenement houses.[14] Zoning ordinances apply both general and location-specific restrictions on certain uses of property. They establish the uses of property in different areas or "zones" within a government's geographic boundaries. For example, residential, commercial, industrial, or agricultural zones determine where housing, shopping, manufacturing, and animal husbandry may or may not occur within the jurisdiction. Mixed-use zones allow a variety of activities to occur in the same area. Ideally, zoning ensures that activities that should be near each other—such as housing and grocery stores—can be near each other and that those activities that should be separated—such as housing and heavy industry—are indeed separate.

The Standard State Zoning Enabling Act, ultimately enacted in nearly every municipality in the nation (except Houston, Tex),[13] was developed by the US Department of Commerce in the 1920s to assist in the delegation and spreading of zoning powers from state to local governments, and it included promotion of "health and general welfare" as one goal of zoning.[15] In 1926, the US Supreme Court confirmed that cities and counties possessed the necessary police powers of the state to regulate public and private land uses for the "health, safety, welfare, and morals" of the people of those jurisdictions.[16] The court stated that the need for zoning regulations "is so apparent that they are now uniformly sustained" and that the "scope of their application must expand or contract to meet the new and different conditions which are constantly coming within the field of their operation."[16]

Conditional use permits (CUPs), sometimes called "special use permits" or "special exceptions," are a refinement of zoning powers whereby the government makes exceptions for specific uses of land otherwise prohibited by general zoning controls as long as the property owner meets certain conditions.[4] With a CUP requirement, a local government can make an *individualized* determination as to suitability of a proposed use in a particular location.[17] CUPs give governments additional flexibility to determine whether a particular proposed use is compatible with existing, neighboring uses of property and afford an opportunity to impose particularized conditions to mitigate potential problems posed by the use. They also give governments the ability to deny a zoning request if the applicant cannot show a community "need" for the proposed use.[18,19]

Public health advocates have reconnected with the historic roots of zoning controls as a mechanism for promoting public health and welfare and have applied the traditional city planning tools of zoning and CUPs to modern issues of public health protection. In addition to a familiar focus on vector control and building codes—which are still pressing public health concerns in communities plagued by antiquated or inadequate public infrastructures or dilapidated housing—public health advocates are using zoning and other land use tools to control the proliferation and negative public health effects of alcohol, tobacco, and gun sales in urban environments. While there is significant variation among states regarding local authority to control these types of outlets,[20,21] zoning tools nonetheless offer creative new opportunities for communities to exert control over public health, safety, and welfare as deemed necessary at the local level.

Alcohol Control and Land Use

Since the mid-1970s, a growing international body of public health research has validated the hypothesis that even relatively small increases in the availability of alcohol generally lead to increases in alcohol consumption, which in turn produce an increase in alcohol-related problems.[22–27] While this general link will vary on the basis of changes in the physical, economic, and social availability of alcohol, as well as the social, cultural, and economic contexts in which availability occurs, the public health literature describes a positive association between physical availability of alcohol and increased sales, independent of prices.[28] This association has led the World Health Organization to conclude that reducing the physical availability of alcohol through limitations on the number and placement of outlets will result in reductions in alcohol-related problems.[29]

Following on the promise of early research showing links between alcohol availability limits and rates of liver cirrhosis[30,31] and drunk driving,[32] researchers in the 1990s used increasingly sophisticated methodologies to establish relationships between alcohol availability and alcohol-related problems. Using 1990 data from 72 cities in Los Angeles County, Scribner et al. found densities of restaurants, liquor stores, and mini-markets (but not bars) to be strongly correlated with motor vehicle crashes causing personal injury.[33]

Subsequent studies have also revealed strong links between violence and alcohol availability. Such links are complex, and they are part of the multicausal relationship between alcohol and violence. The increased consumption arising from greater alcohol availability may lead to more frequent incidents of intoxication, in which personal expectations about alcohol's supportive role in violence or alcohol's pharmacological effects as a disinhibitor of aggressive impulses may come into play.[34] Increased numbers of drinking places may provide situationally appropriate settings for violence[35] or for group intoxication, which may increase the possibility of violence occurring.[34]

Research support for the link between alcohol and violence comes from subsequent work by Scribner et al., who found that, independent of measured confounders such as unemployment, racial/ethnic makeup, income, and age, alcohol outlet density was correlated with violent assault to the extent that one outlet was associated with 3.4 additional offenses in 1990.[36] Similarly, Speer et al. found, in analyzing various census tracts in Newark, NJ, that alcohol outlet density was a significant predictor of rates of violent crime.[37] Alaniz et al., looking at violence among young people in 3

cities, again found a statistically significant relationship with outlet density.[38]

Recent studies have refined our understanding of the connection between physical availability by showing a significant relationship between alcohol problems and alcohol availability in census tracts and the even smaller unit of census blocks.[39] This new work offers 2 important lessons. For researchers, it suggests the importance of examining alcohol availability in the smallest units possible; aggregating data in large geographic units may mask the connection between availability and associated problems. For practitioners, the research suggests the importance of zoning decisions regarding individual outlets within a particular neighborhood setting.

In the 1980s, alcohol control advocates began community-based campaigns designed to limit the proliferation of retail alcohol outlets and to address the secondary effects of alcohol sales, such as public and domestic violence, drunk driving, loitering, prostitution, illegal drug sales, and the like, based on the public health research just described. Over the past 2 decades, alcohol control advocates have secured passage of innovative local ordinances, subjected them to testing in the courts, and compiled substantial experience in their implementation.

Innovative local ordinances. In the mid-1980s, California communities took the lead in a trend toward passing zoning and CUP regulations affecting the location and operation of alcohol outlets.[40] By 1993, approximately half of the state's 475 cities had CUP requirements for on-sale and off-sale alcohol outlets.[41] Such ordinances placed restrictions on new alcohol outlets, including, for example, limits on the number and concentration of outlets in a neighborhood, limits on placement of outlets in proximity to each other and to schools or playgrounds, and restrictions on hours of service and the amount and nature of signage visible from the street.

Testing in the courts. Courts have confirmed that local governments may impose alcohol-related land use restrictions even in localities where the state has preempted local control over the sale of alcohol products. The courts base this determination on the rational relationship between alcohol availability and its secondary effects on public health, safety, and welfare.[42,43] Courts have found that local power over land use is so strong that it can be used to regulate the operation of alcohol outlets despite the state's exclusive authority over alcohol sales.

For example, in the aftermath of the 1992 Los Angeles riots, liquor store owners in the city's heavily damaged south-central neighborhood sought to rebuild. However, in the years before the riots, Los Angeles, like many other California communities, had begun requiring CUPs for all new alcohol outlets in the city.[42] (Typical prerequisites to rebuilding required an owner "to agree to remove graffiti promptly, provide adequate lighting, remove trash, provide a security guard and, in some instances, limit hours of operation."[42]) The CUP requirement essentially blocked many stores from reopening because, having been closed for a certain period of time, they were considered "new" stores under the law and therefore required CUPs.[42] Affected owners challenged the CUP ordinance as being both preempted by state law and unconstitutional.[42] The Court of Appeals upheld the city's ordinance, confirming that "the local regulation is a valid exercise of the City's authority to enact zoning and land-use regulations."[42]

A similar challenge followed the enactment of the city of Oakland's CUP ordinance.[43] Existing alcohol outlets claimed that the imposition of performance standards for the operation of existing liquor stores was preempted by state law and unconstitutional.[43] The Court of Appeals again confirmed a local government's power in using land use ordinances to protect public health, holding that "a city may properly enact a local ordinance to control and abate nuisance activities, despite the fact that the business that would be regulated by the ordinance possessed grandfather rights that might ordinarily render it immune from compliance with local ordinances."[43] "No business—not even an alcoholic beverage sales establishment regulated by state law—has a vested right to conduct its business in a manner that attracts public nuisances and encourages criminal activities near its premises."[43]

In summary, a robust set of research studies demonstrate the link between alcohol availability and alcohol-related problems. Furthermore, court decisions affirm that a local government, in pursuit of public health goals, may employ land use law to influence alcohol availability. The research findings provide a basis for hypothesizing a similar effect for tobacco availability.

Tobacco Control and Land Use

Many state and local governments have passed measures regulating retail sales practices of tobacco outlets (e.g., laws prohibiting sales to minors, laws banning self-service displays of tobacco products, laws requiring retail clerks to be of legal age to buy tobacco in order to sell tobacco, and even laws regulating the minimum price of tobacco). However, largely unexplored by tobacco control advocates are the zoning tools used in alcohol control that could limit the location and number of tobacco retail outlets.

Although no court has yet issued an opinion directly addressing tobacco-related land use controls, it is likely that regulating land use to further tobacco control policy is on an even stronger legal footing than it is in the case of alcohol control. California and many other states have preemptive state laws governing alcohol sales. As a result, local communities must rely on the secondary effects of alcohol consumption to justify land use restrictions to overcome the legal challenge that state law preempts any local regulation of alcohol sales. Because most states do not have laws that preempt local regulation of tobacco sales,[20] communities can impose land use restrictions expressly regulating tobacco sales themselves in addition to regulating the secondary effects of to-

bacco use (such as premature death and disability and the illegal sale of tobacco products to minors).

Given that tobacco products produce a significant negative impact on the health and welfare of a community and are also associated with illegal behavior, it is reasonable—and certainly should meet the very low legal bar of being "rational"—for local governments to use their zoning powers to regulate the location of tobacco retailers. This government role is especially important in instances in which youth access is concerned. One study showed that 57% of 10th graders and 38% of 8th graders perceive that it would be easy for them to obtain cigarettes from a retail source,[44] and the best predictor of adolescent experimentation with cigarettes is the perception that they are easily available.[45]

The questioning of whether youth access laws control the availability of tobacco to youths[46] and the near inability of local governments to control tobacco advertising after the US Supreme Court's decision in *Lorillard v Reilly*[47] mean that new approaches are needed to control the accessibility, availability, and prominence of tobacco products in local communities. The effectiveness of tobacco-related land use controls in limiting the negative health consequences and illegal behavior associated with tobacco remains to be demonstrated. However, it is the fact that a positive effect is *plausible* that answers the threshold question of whether such controls are *legal*.

In the absence of evidence showing the particular types of tobacco-related land use controls that might produce better results, but with reflection on the lessons learned from the success of land use regulation in alcohol control, a variety of tobacco-related possibilities come to mind. For example, to diminish the harm caused by tobacco in a community, local governments can use zoning and CUPs to:

- Require that tobacco outlets be located away from areas frequented by children (e.g., schools, playgrounds, residential areas, and video arcades)[48]
- Restrict new discount tobacco outlets to light industrial or industrial zones to control access to cheap cigarettes among price-sensitive populations, especially young people[49]
- Limit the total number of tobacco outlets in a community if the city or county determines that sufficient outlets for tobacco products already exist[50]
- Limit the proximity of all tobacco outlets to each other, ensuring, for example, that a tobacco outlet does not occupy each corner at an intersection

Firearms Control and Land Use

Several California communities have invoked their land use authority to limit the location of firearms dealers to commercially zoned areas.[48] The city of Lafayette, Calif, enacted an ordinance that not only limited firearms dealers to commercial zones but also prohibited dealers from locating near elementary, middle, and high schools; preschools; day-care centers; other firearms dealers; liquor stores and bars; and residentially zoned areas.[48] In upholding the city's ordinance, the California Court of Appeals confirmed that municipalities are entitled to confine commercial activities to certain districts and that they may further limit activities within those districts by requiring use permits: "It is well settled that a municipality may divide land into districts and prescribe regulations governing the uses permitted therein, and that zoning ordinances, when reasonable in object and not arbitrary in operation, constitute a justifiable exercise of police power."[48] The legal issue, once again, is whether there is a rational basis for the zoning decision.[48]

Nutrition and Land Use

The same land use tools that control the location and operation of alcohol outlets, tobacco outlets, and firearms dealers logically can be extended to issues related to nutrition. Child and adolescent obesity is an epidemic in the United States.[51] Poor nutrition and physical inactivity are responsible for more preventable deaths in the United States than AIDS, violence, drugs, alcohol, and car crashes combined.[52]

The prevalence of "fast food" outlets offering menus filled with nutritionally deficient food and promoting "super-sized" portions, in combination with a scarcity of healthy alternatives, is an important public health issue. It is reasonable—and certainly "rational"—for a local government to employ its land use powers to mitigate the rising epidemic of poor nutrition. One of many imaginable approaches would be to require restaurants falling below certain nutritional standards—perhaps in combination with other criteria—to obtain a CUP imposing any of a wide variety of restrictions.

The purpose of such a CUP is at least twofold: (1) to encourage restaurants to improve the nutritional quality of their food, or at least provide alternative healthy meals, and (2) to displace those "fast food" outlets that do not improve in an effort to open the marketplace to competition from healthier restaurants. Imagining only what could be done—not necessarily what should be done—local governments could impose on nutritionally deficient "fast food" restaurants land use requirements that:

- Prohibit the distribution of toys and promotional games, the presence of play equipment, or the presence of video or other games at fast food outlets
- Require fast food outlets to locate a minimum distance from youth-oriented facilities such as schools and playgrounds
- Limit the total number or per capita number of fast food outlets in a community
- Limit the proximity of all fast food outlets to each other
- Charge a fee to fast food outlets and use the proceeds to mitigate the impact of poor nutritional content (e.g., construct parks, fund after-school programs, or provide nutrition education)
- Prohibit drive-through service

CONCLUSIONS

As these examples and possibilities demonstrate, the public health field is only beginning to take advantage of the potential inherent in the police powers of local governments to regulate and attach conditions to land use. In this context, further exploration of this promising approach and extension of its application to new arenas, such as tobacco and nutrition, appear even more significant as tools in the hands of public health authorities and advocates. ■

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M. Ashe coordinated the team of authors who developed this article. She wrote the sections on police powers and land use controls. D. Jernigan collaborated on the concept and framing of the article and took primary responsibility for the section on alcohol control. R. Kline collaborated on the concept and framing of the article and took primary responsibility for the sections on tobacco control, gun control, and nutrition. R. Galaz provided some of the initial legal research and copyediting for the article.

References

1. Maantay J. Zoning, equity, and public health. *Am J Public Health.* 2001;91:1033–1041.

2. Gostin LO. *Public Health Law: Power, Duty, Restraint.* Berkeley, Calif: University of California Press; 2000.

3. *Chicago, B. & O. Railway Co. v Illinois*, 200 US 561, 592 (1906).

4. Fulton W. *Guide to California Planning.* Point Arena, Calif: Solano Press; 1999.

5. Teret SP, Christoffel T. Injury prevention and the law. In: Goodman R, Rothstein M, Hoffman R, et al., eds. *Law in Public Health Practice.* New York, NY: Oxford University Press Inc; 2003: 399–415.

6. *Miller v Board of Public Works*, 195 Cal 477, 484 (1925).

7. *Birkenfield v City of Berkeley*, 17 Cal3d 129 (1976).

8. *Cosolidated Rock Products v. City of Los Angeles*, 57 Cal2d 515, 522 (1962).

9. *Strumsky v San Diego County Employees Retirement Ass'n*, 11 Cal3d 28, 34–35 (1974).

10. *Arnel Development Co. v City of Costa Mesa*, 28 Cal3d 511, 524 (1980).

11. *Lockard v City of Los Angeles*, 33 Cal2d 453, 460 (1949).

12. Section V—police power. In: *The California Municipal Handbook.* Sacramento, Calif: League of California Cities; 2001:V1.

13. Platt RH. *Land Use and Society: Geography, Law and Public Policy.* Washington, DC: Island Press; 1996.

14. Barnett J. *Urban Design as Public Policy.* New York, NY: Architectural Record Books; 1974.

15. Richards JG. Zoning for direct social control. *Duke Law J.* 1982;5:761–774.

16. *Village of Euclid v Amber Realty Co.*, 272 US 365 (1926).

17. *Saad v City of Berkeley*, 24 Cal App 4th 1206 (1994).

18. Ellickson RC, Tarlock AD. *Land-Use Controls: Cases and Materials.* Boston, Mass: Little Brown & Co; 1981.

19. *Lucky Stores Inc. v Board of Appeals of Montgomery County*, 270 Md 513 (1973).

20. *Allied Vending v City of Bowie*, 332 Md 279 (1993).

21. *Montgomery County v Atlantic Guns*, 302 Md 540 (1985).

22. Beauchamp D. *Beyond Alcoholism: Alcohol and Public Health Policy.* Philadelphia, Pa: Temple University Press; 1980.

23. Bruun K, Edwards G, Lumio M, et al. *Alcohol Control Policies in Public Health Perspective.* Helsinki, Finland: Finnish Foundation for Alcohol Studies; 1975.

24. Mäkelä K, Room R, Single E, et al. *Alcohol, Society, and the State: 1. A Comparative Study of Alcohol Control.* Toronto, Ontario, Canada: Addiction Research Foundation; 1981.

25. Moore M, Gerstein D. *Alcohol and Public Policy: Beyond the Shadow of Prohibition.* Washington, DC: National Academy Press; 1981.

26. Mosher JF, Jernigan D. Making the link: a public health approach to preventing alcohol-related violence and crime. *J Subst Use.* 2001;6:273–289.

27. Room R, Rossow I. Share of violence attributable to drinking. *J Subst Use.* 2001;6:218–228.

28. Gruenewald PJ, Ponicki WR, Holder HD. Relationship of outlet densities to alcohol consumption: a time series cross-sectional analysis. *Alcohol Clin Exp Res.* 1993;17:38–47.

29. Edwards G, Anderson P, Babor TF, et al. *Alcohol Policy and the Public Good.* Oxford, England: Oxford University Press Inc; 1994.

30. Parker DA, Wolz MW. Alcohol problems and the availability of alcohol. *Alcohol Clin Exp Res.* 1979;3:309–312.

31. Colon I. Alcohol availability and cirrhosis mortality rates by gender and race. *Am J Public Health.* 1981;71:1325–1328.

32. Rabow J, Watts RK. Alcohol availability and alcohol-related problems in 213 California cities. *Alcohol Clin Exp Res.* 1983;7:47–58.

33. Scribner RA, MacKinnon DP, Dwyer JH. Alcohol outlet density and motor vehicle crashes in Los Angeles County cities. *J Stud Alcohol.* 1994;55:447–453.

34. Graham K, Leonard K, Room R, et al. Alcohol and aggression: current directions in research on understanding and preventing intoxicated aggression. *Addiction.* 1998;93:650–676.

35. Pernanen K. Prevention of alcohol-related violence. *Contemp Drug Problems.* 1998;25:477–509.

36. Scribner RA, MacKinnon DP, Dwyer JH. Risk of assaultive violence and alcohol availability in Los Angeles County. *Am J Public Health.* 1995;85:335–340.

37. Speer PW, Gorman DM, Labouvie EW, Ontkush MJ. Violent crime and alcohol availability: relationships in an urban community. *J Public Health Policy.* 1998;19:303–318.

38. Alaniz ML, Cartmill RS, Parker RN. Immigrants and violence: the importance of neighborhood context. *Hispanic J Behav Sci.* 1998;20:155–174.

39. Gorman DM, Speer PW, Gruenewald PJ, Labouvie EW. Spatial dynamics of alcohol availability, neighborhood structure and violent crime. *J Stud Alcohol.* 2001;62:628–636.

40. Wittman F, Hilton M. Uses of planning and zoning ordinances to regulate alcohol outlets in California cities. In: Holder HD, ed. *Control Issues in Alcohol Abuse Prevention: Strategies for States and Communities.* Greenwich, Conn: JAI Press Inc; 1987:337–366.

41. Wittman F. Local control to prevent problems of alcohol availability: experience in California communities. In: Plant M, Single E, Stockwell T, eds. *Alcohol: Minimizing the Harm. What Works?* New York, NY: Free Association Books Ltd; 1997:43–71.

42. *Korean American Legal Advocacy Foundation v City of Los Angeles*, 23 Cal App 4th 376, 382–383, 390 (1994).

43. *City of Oakland v Superior Court*, 45 Cal App 4th 740, 747–749, 756 (1996).

44. Tobacco Control Section, California Dept of Health Services. Independent evaluation of the California Tobacco Control Prevention and Education Program: wave 2 data, 1998, wave 1 and wave 2 data comparisons 1996–1998. Available at: http://www.dhs.ca.gov/tobacco/documents/Wave2IEreport.pdf. Accessed November 24, 2001.

45. Robinson LA, Klesges RC, Zbikowski SM, Glaser R. Predictors of risk for different states of adolescent smoking in a biracial sample. *J Consult Clin Psychol.* 1997;65:653–657.

46. Ling PM, Landman A, Glantz SA. It is time to abandon youth access tobacco programs. *Tob Control.* 2002;11:2–5.

47. *Lorillard Tobacco Co. v Reilly*, 533 US 525 (2001).

48. *Suter v City of Lafayette*, 57 Cal App 4th 1109, 1133 (1997).

49. *Lakeland Lounge of Jackson Inc. v City of Jackson, Mississippi, 973 F2d 1255, 1258–1259 (5th Cir 1992).*

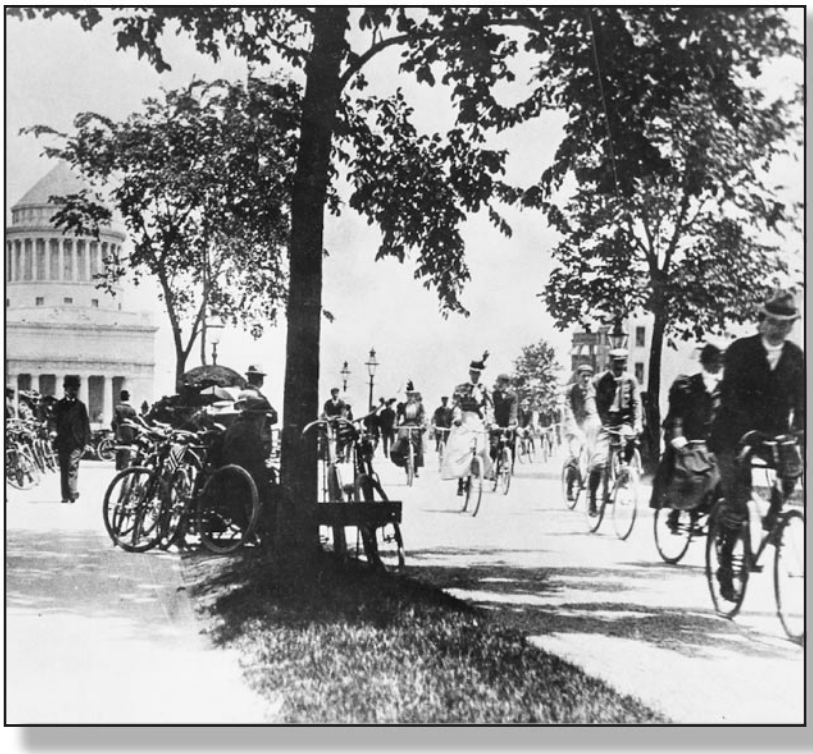
50. *Van Sicklen v Browne*, 15 Cal App 3d 122, 127–128 (1971).

51. Centers for Disease Control and Prevention. Overweight and obesity. Available at: http://www.cdc.gov/nccdphp/dnpa/obesity/index.htm. Accessed June 30, 2003.

52. McGinnis JM, Foege WH. Actual causes of death in the United States. *JAMA.* 1993;270:2207–2212.

Bicycling for Pleasure and Power

Elizabeth Fee and Theodore M. Brown



Source. **Associated Press.**

THE FIRST BICYCLES marketed in the 1830s were expensive and exhausting to operate. The 1860s saw the first crank-driven "velocipedes" and the 1870s the high-wheeled "ordinaries," which were easier to manage although still quite dangerous. Then, in the 1880s, the "safety" bicycle was developed, with wheels of the same moderate size, pneumatic tires, and pedals and rider positioned between the wheels. Marketed at a price that most middle-class people could afford, bicycles suddenly became a popular passion.[1]

Bicycling, for most, was much more fun than the rather tedious practice of regimental gymnastics and other forms of calisthenics. It was more sociable and freeing—a form of transportation as well as of exercise—and it could be practiced in the open air, on country or city roads, in parks or along urban parkways (as in this photograph taken on Riverside Drive, New York City, sometime in the 1890s), alone or with friends. Bicycling did not require expensive clothing or equipment; unlike horse riding or golf, it was relatively democratic and available to many.

Physicians debated the health benefits and hazards of bicycling, especially for women. Some hailed it as the century's greatest contribution to health, a cure for dyspepsia, anemia, obesity, asthma, varicose veins, heart disease, and diabetes, among other ills. Bicycling, some said, could free a person from any craving for artificial stimulants or narcotics; it could cure nervousness, conquer insomnia, and bring families together as husband, wife, and children all bicycled together.

Others warned of the possible dangers of the bicycle. Bicyclists could run into each other, or into horses, lampposts, or pedestrians; "Death by the Wheel" was a new heading in obituary columns. There were also the "diseases of cycling": "kyphosis bicyclistarum"—otherwise known as "cyclist's spine" or "cyclist's stoop"—"bicycle hernia," "bicycle heart," "cyclist's neurosis," "cyclist's sore throat," and even "bicycle face"—the strained, set look brought on by the "incessant tension" of maintaining one's balance on a 2-wheeled machine.

The fact that women took to the bicycle with great enthusiasm generated decidedly mixed responses. Robert Latou Dickenson, a New York obstetrician, argued that bicycling was the best single exercise for strengthening the pelvis and promoting healthy childbearing. Others feared that women enamored of their bicycles would reject childbearing altogether. They worried that women bicyclists were casting aside their corsets and high heels in favor of various forms of more natural dress—from relatively modest split skirts to "unfeminine" knickerbockers or bloomer-type outfits.[2] But the new women bicyclists were not to be deterred. As Marie E. Ward explained in 1896, "the bicycle supplies . . . a new pleasure—the pleasure of going where one wills, because one wills. . . . Riding the wheel, our own powers are revealed to us. . . . You have conquered a new world, and exultingly you take possession of it."[3] ■

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References

1. Whorton JC. *Crusaders for Fitness: The History of American Health Reformers.* Princeton, NJ: Princeton University Press; 1982:304–330.

2. Marks P. *Bicycles, Bangs, and Bloomers: The New Woman in the Popular Press.* Lexington, Ky: University Press of Kentucky; 1990:174–203.

3. Ward MEG. *The Common Sense of Bicycling: Bicycling for Ladies.* Quoted in: Rosenzweig R, Blackmar E. *The Park and the People: A History of Central Park.* Ithaca, NY: Cornell University Press; 1992:323.

Smart Growth: A Prescription for Livable Cities

Alyson L. Geller, MPH

FOR MANY, THE GREAT AMERICAN Dream is associated with large, single-family homes, lots of land, and a feeling of independence. Now, public health and urban planning professionals claim this vision has gone too far. They blame a phenomenon called sprawl for a host of problems, from obesity and traffic injuries to environmental destruction. A movement called Smart Growth is challenging the way we build, work, and live, and is encouraging us to look at communities not only as places to live but as vehicles to promote health and well-being.

SMART GROWTH AND CHOICES

According to Don Chen of Smart Growth America, a nationwide coalition of over 60 public interest groups, low-density suburban growth, or sprawl, has 4 dimensions: a population that is widely dispersed in low-density development; rigidly separated homes, shops, and workplaces; a network of roads marked by huge blocks and poor access; and a lack of well-defined, thriving activity centers, such as downtowns and town centers.[1] Most of the other features usually associated with sprawl—a lack of transportation choices, dependence on the automobile, relative uniformity of housing options, and the difficulty of walking—are a result of these conditions.

There are many who defend low-density suburban growth because of the opportunities for home ownership and independence. Suburban neighborhoods away from commercial areas offer the opportunity to own large pieces of property. Such developments tend to be more homogenous, which some say contributes to better schools and lower crime rates. And while living in outlying suburbs necessitates private transportation, many say they prefer the independence and freedom of driving their own automobiles.

Sprawl has been criticized for being a financial and social drain. Outlying suburbs often require more costly infrastructure (roads, water, sewers, and other services); suburban development composed primarily of housing often lacks the tax base necessary to cover such expenses. Urban centers also pay a price when residents leave for the suburbs, depleting cities of economic and social diversity as well as a strong tax base.

Public health officials have voiced a number of concerns about sprawl's impact on health and safety. Most notably, critics cite automobile dependence associated with sprawl for promoting sedentary lifestyle habits and contributing to traffic injuries and air quality problems.

Automobile dependence has been associated with an increasingly sedentary culture in the United States, which in turn gen-

erated an epidemic rise in obesity. In 2000, a total of 38.8 million American adults met the classification for obesity, according to the Centers for Disease Control and Prevention (CDC), putting themselves at risk for chronic diseases including diabetes, high blood pressure, coronary artery disease, osteoporosis, cancer, and stroke.[2] Physical inactivity is an independent risk factor for chronic disease. People who are physically inactive are at a two- to threefold greater risk for premature mortality than their physically active counterparts.[3,4]

Motor vehicles are responsible for one third to one half of the smog in most metropolitan areas; over 113 million Americans live in cities with polluted air.[5] Topping the health effects associated with air pollution, asthma affects approximately 17 million adults and over 4 million children in the United States.

About 41 000 Americans are killed every year on our nation's roadways; approximately 13% of traffic fatalities are pedestrians or cyclists.[6] Among CDC recommendations to reduce such fatalities are the use of pedestrian bridges and traffic islands, narrower streets, more sidewalks and pedestrian malls, and denser community areas that combine work, shopping, and residences—all Smart Growth measures currently being adopted in communities across the country.

Other concerns associated with sprawl focus on the environment: the extensive land consumption associated with sprawl has been criticized for habitat loss and fragmentation, wetland destruction, and degradation of air and water quality.

The Smart Growth movement involves professionals from many disciplines, including planners, designers, builders, transportation officials, crime prevention specialists, environmentalists, politicians, public heath advocates, and a range of citizen groups. Its advocates include the Environmental Protection Agency; private organizations like the Urban Land Institute, the Robert Wood Johnson Foundation, and the nationwide coalition Smart Growth America; a range of public health officials; pedestrian and biking advocates; and leaders at all levels of government. Such a broad coalition necessarily has varied goals, but the movement's main objectives can be summarized as follows: improving quality of life for all citizens, promoting healthy behaviors, minimizing hazards to people, and protecting and restoring the natural environment.

Smart Growth strives to protect farmland and open space, revitalize neighborhoods, and provide more transportation choices. Smart Growth encourages reinvestment in existing communities, more efficient use of existing infrastructure, and transportation choices. It promotes compact development and the creation of mixed-use communities that integrate a range of housing and commercial services and serve a variety of income levels. However, a central theme in the Smart Growth movement is that of choice. Advocates stress that well-designed communities offer variety in housing, transportation, employment, and recreation.

Within public health, a parallel movement called Active Living emphasizes such elements as bicycle- and pedestrian-oriented design, traffic calming, mixed-use development, and "safe routes to school" programs that allow residents to integrate physical activity such as walking and bicycling into their daily lives.

SMART GROWTH AT THE LOCAL, STATE, AND FEDERAL LEVEL

Proponents of Smart Growth are most active at the local level, where land use decisions are usually made. Still, national and state policy is a significant part of the equation, as it can provide incentives or disincentives for local governments, set standards, and act as a watchdog. Democratic

Left: Suburban development encroaching on farmland.

Below: Saturday market at Skidmore Fountain in Portland, Ore.

Courtesy of TriMet, Portland, Ore.

"Smart Growth is so many different things. It's not just transportation; it's a mindset towards creating a more holistic community. We've talked about quality of life. And what has been more fundamental to quality of life than physical health?"

—Barbara McCann, Executive Director, Smart Growth America

Courtesy of Milwaukee Department of City Development.

RiverWalk project, Milwaukee, Wis.

and Republican governors in states across the country are coordinating with local jurisdictions to reinvigorate existing communities and promote transportation planning and more environmentally sound land use. Anticipating the renewal of the federal Transportation Efficiency Act for the 21st Century (TEA-21), a range of constituencies, from grassroots to state and federal legislators, are pushing for investments in light rail and pedestrian and bicycle infrastructure.

Smart Growth initiatives are being pursued in communities across the country. A few examples are outlined below.

Local Initiatives

A river comes to life and a freeway overpass comes down. Milwaukee's Smart Growth has been driven by a mayor who is focused on building a vibrant community. Mayor John Norquist's initiatives have included the removal of the elevated Park East Freeway spur and the cleanup and development of Milwaukee's riverfront.

The freeway demolition project, initiated in April 2002, released 26 acres of riverfront for redevelopment and preserved traffic flow with a 3-lane boulevard and pedestrian bridge, according to Norquist.

Milwaukee's RiverWalk project, launched in 1994, transformed a heavily industrialized and isolated riverfront area. A partnership between the city and downtown property owners turned the river into a city hub that has fueled a housing boom, spawned a number of new restaurants, shops, and green space, and in the process created a broader constituency for cleaning up the Milwaukee River.

Norquist emphasizes that the RiverWalk enhanced the community, not just because it introduced a walkway but because it is connected to the city's street grid.

Smart Growth's poster city. Portland, Ore, has earned a reputation as the Smart Growth gold standard by its active citizenry. and leadership at local and state levels, including the enthusiastic participation of Oregon Congressman and bicycle enthusiast Earl Blumenauer.

Thirty years ago, Portland was strangled with traffic congestion. Under the leadership of then-mayor Neil Goldschmidt (later US secretary of transportation), the city revived its downtown area and surrounding neighborhoods, investing in a multimodal regional transportation system including an extensive light rail, a bus network, and the country's first modern streetcar line.

The city was the first in the country to undertake a comprehensive Pedestrian Master Plan. Nearly 800 traffic-calming devices such as speed bumps and traffic circles and 221 miles of bikeways allow pedestrians and cyclists to commute safely to downtown.[7]

The city's legendary parks and other green space benefit from a 26-year statewide land-use planning program marked by the use of urban growth boundaries and the preservation

> *"People must feel empowered on a level that is personal to them—individual communities have individual needs."*
> *—Rich Killingsworth, Director, Active Living by Design*

of forest land. Among the 100 largest cities in the United States, Portland was rated number one in meeting key Healthy People 2000 goals.[8] "This achievement is not just about conventional preventive health care," says Multnomah County Health Department Director Lillian Shirley, "but includes issues of housing, urban planning, and alternative transportation."[9]

Public transit, mixed-use communities, and Cinderella stories. According to Smart Growth America, transit-oriented development is an obvious way to integrate transportation and land-use planning, since it clusters housing and commercial activities around stations. Advocates claim that such development boosts transit ridership and provides a reliable market base for local businesses. Cities such as Denver and Dallas have created transit-oriented, mixed-use communities, and the public seems to be responding with enthusiasm.

Dallas has laid 44 miles of light rail, supporting 60 000 riders a day and spawning a trend in retail, residential, and office development around rail stations, explained Jack Wierzenski, an assistant vice president at Dallas Area Rapid Transit. In Denver, whose metropolitan area continues to grow at a rapid pace, a light rail system connects suburbs from all directions to the downtown, and a free shuttle bus runs the length of the downtown spine. A decaying shopping mall known as Cinderella City has been transformed into a transit-oriented, mixed-use community where apartments sit atop office and retail space, all of which are within walking distance of the Englewood light rail stop.

State Level Initiatives

Maryland. In 2001, then–Maryland Governor Parris Glendening helped put the state on the cutting edge of the Smart Growth movement, creating a cabinet-level position that focused exclusively on transportation, land use, and growth issues, generating incentives to encourage Smart Growth, and signing legislation that prevented state funds from being used for infrastructure projects that induce sprawl. Maryland's Office of Smart Growth serves as an information clearinghouse, developing outreach and education programs and assisting local officials, developers, the news media, and citizen groups. Most importantly, the office helps local jurisdictions, developers, and the public to prepare, finance, and develop projects that are consistent with Smart Growth policies.

Glendening's Community Legacy program has awarded $15.5 million in revitalization grants, funding projects in 40 communities. Says former Maryland Smart Growth cabinet secretary Harriet Tregoning, "Where 80% of funds used to be used for building new schools, that percentage is now used to repair existing schools." This type of renovation preserves green space and keeps schools close to residential centers.

To fulfill his goal of doubling transit ridership by 2020, Glendening allocated $50 million and provided financial incentives such as discounted land near rail stations. These steps helped to encourage commercial development and safety improvements near stations and provided people the option of living near their workplace. Bicycle and pedestrian initiatives received enhanced funding; open-space programs preserved 300 000 acres from development and acquired and restored parkland, forests, and wildlife corridors. Economic incentives provided to developers encouraged brownfields cleanup and development, again using existing infrastructure while improving distressed urban areas.

> *"Neither the State nor local governments can afford to go it alone if we are to enhance the vitality of our communities and preserve the State's most valuable forests and farmland."*
>
> *—Maryland Governor's Office of Smart Growth*[11]

Courtesy of Office of Smart Growth, Maryland Dept of Planning.

Glendening is now out of office, but the Office of Smart Growth has been retained by the current governor, Robert Ehrlich. Says Tregoning, if Erlich is like other governors who inherited Smart Growth initiatives from their predecessors, he will likely make these issues his own.

New Jersey. Governor James McGreevey recently made his 2003 State of the State speech about Smart Growth, focusing on infill (development that maximizes use of existing infrastructure) and revitalization. Claiming that each day the state loses 50 acres to sprawl, McGreevey pledged legal and zoning tools to control and manage growth.[11] The governor's Smart Growth checklist includes a cabinet-level Smart Growth Policy Council, a "Smart Growth

> *"If you want to build in over-developed or protected areas we will do everything in our power to stop you. However, if you want to build and grow consistent with Smart Growth, then we will help you get regulatory approvals quickly and make sure the infrastructure is there to support you."*
>
> *—New Jersey Governor James McGreevey*[11]

Shield" calling for the state attorney general to intervene when Smart Growth planning is challenged, and financial mechanisms that will enable conservation. McGreevey has vowed to preserve 20 000 acres of farmland a year, while upgrading 200 local parks, creating at least 2 state parks, and planting 100 000 trees.[11] He has also called for invigorating urban centers, older suburbs, and rural towns by redeveloping brownfields and steering infrastructure spending to these areas.

Federal Level Initiatives

The federal Environmental Protection Agency (EPA) has become a Smart Growth advocate, offering resources to help communities with environmental problem solving and growth planning through community grants and projects. The agency has established best-management practices for such issues as soil erosion and wastewater treatment, and works with state officials, city planners, and a range of advocacy and citizen groups on these problems.

The most significant piece of federal Smart Growth legislation on the table is TEA-3, the third iteration of the Intermodal Surface Transportation Efficiency Act, established by Congress in 1991 and set for renewal in September 2003. Currently referred to as TEA-21, the law has the potential to be a good source of funding for transit, bikes, and pedestrians, but faces significant roadblocks. The American Road and Transportation Builders Association wants increased funding of roads and highways, and President Bush's budget request for the federal fiscal year beginning October 1, 2003, calls for a 6% hike in highway spending with no increase in federal transit spending.

According to the Surface Transportation Policy Project, the states are not investing enough of their federal transportation dollars into protecting people who walk. While 12% of all traffic deaths are pedestrians (13.6% if bicyclists are included), only 0.7% of federal transportation construction, operations, and maintenance funds are spent to ensure a safe walking environment.[12]

Alongside numerous advocacy groups, the fight for increased transit resources will be led by James Oberstar, a member of the House Transportation Committee, and Oregon Congressman Earl Blumenauer, who are both pushing to preserve and expand bicycle and pedestrian programs, mass transit, and air quality measures. Blumenauer has met with citizens in hundreds of communities throughout the United States as part of his Livable Communities Task Force, discussing ways to improve land use, the environment, and transportation. With Representatives Oberstar, Peter DeFazio, and Edward Kennedy, Blumenauer founded the Congressional Bike Caucus, a bipartisan group that provides congressional leadership to bicycle and pedestrian advocates.

Courtesy of Maryland Department of the Environment.

Before and after images of a brownfield renovation: the American Can Company, Baltimore, Md.

THE FUTURE OF SMART GROWTH

Although the movement has gathered a strong following, not everyone is convinced that Smart Growth works. The organization Demographia, which refers to itself as "pro-choice, with respect to urban development," argues that Smart Growth in fact limits choice and opportunity. The group asserts that initiatives such as urban growth boundaries and "development impact fees" increase housing costs, thereby reducing home ownership, especially for minorities. They are also skeptical about transit initiatives, contending that outside of downtown corridors, there is little that transit can do to reduce traffic congestion, and that, for the most part, public transportation is unable to compete with the convenience of the automobile.[13]

Peter Gordon, professor of planning and economics at the University of Southern California's School of Urban Planning and Development, agrees, arguing that a major shift to transit is highly improbable, and predicting that higher densities will actually bring more congestion. Challenging the presumption that "suburbanites are living lives of quiet desperation and isolation," Gordon insists that citizens are voting for spacious living, "so by all means let them have what they are voting for."[14]

Smart Growth measures are still relatively new and untested. Many are hesitant to invest in something new. "If it's not broken, why fix it? Behavior is hard to change," says Rich Killingsworth, citing problems such as outdated building and zoning codes and cautious development communities.

Opinions on Smart Growth's efficacy still vary, but it is clearly becoming a part of the urban revitalization landscape. One of its greatest assets may be its scope, encompassing so many elements and disciplines, and offering com-

munities a range of choices according to their needs. For some, it might be extensive transit development to ease traffic congestion; for others, it might be a "safe routes to school" program that puts parents at ease and enables children to walk every day.

By emphasizing and enabling such elements as increased physical activity, healthier environments, and more interactive communities, Smart Growth has enormous potential to enhance the health of populations. Certainly, the public health field plays a vital role in defining and evaluating the indicators of Smart Growth that actually do improve health.

Advocates like Smart Growth America's Barbara McCann and James Corless of the Surface Transportation Policy Project emphasize the need to get citizens involved and show them that Smart Growth is about choice in housing, transportation, and lifestyle. Smart Growth comes in all shapes and sizes, says Corless; "People are ready for it—it just needs to be presented in the right way." ■

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Alyson L. Geller is a freelance health journalist who has written for consumer and academic publications.

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References

1. Smart Growth America. Measuring sprawl and its impact: the character and consequences of urban expansion. Available at: http://www.smartgrowthamerica.org/sprawlindex/sprawlexecsum.html. Accessed February 7, 2003.

2. Centers for Disease Control and Prevention. Obesity trends, 1985–2001. Available at: http://www.cdc.gov/nccdphp/dnpa/obesity/trend/maps/index.htm. Accessed February 13, 2003.

3. Wei M, Kampert JB, Barlow CE, et al. Relationship between low cardiorespiratory fitness and mortality in normal-weight, overweight, and obese men. *JAMA*. 1999;282:1547–1553.

4. Blair SN, Kampert JB, Kohl HW 3rd, et al. Influences of cardiorespiratory fitness and other precursors on cardiovascular disease and all-cause mortality in men and women. *JAMA*. In press.

5. Surface Transportation Policy Project website. Transportation and Health. Available at http://www.transact.org/library/factsheets/health.asp. Accessed March 13, 2003.

6. US Dept of Transportation, National Highway Traffic Safety Administration. Fatality Analysis Reporting System 2001. Available at: http://www-fars.nhtsa.dot.gov. Accessed March 17, 2003.

7. 1998–2000 Biennial Report. Portland Office of Transportation. Portland, Ore.

8. *Healthy People 2010: Understanding and Improving Health.* Washington, DC: US Department of Health and Human Services; 2001. Also available at: http://web.health.gov/healthypeople/document. Accessed August 12, 2003.

9. Shirley L. Urban parks: what's health got to do with it? *Oregonian.* October 28, 2002: C7.

10. Maryland Governor's Office of Smart Growth: mission statement. Available at: http://www.smartgrowth.state.md.us/mission.htm. Accessed February 12, 2003.

11. Governor James McGreevey. State of the State speech. January 14, 2003. Available at: http://www.state.nj.us/sos2003/speech_text.html. Accessed February 27, 2003.

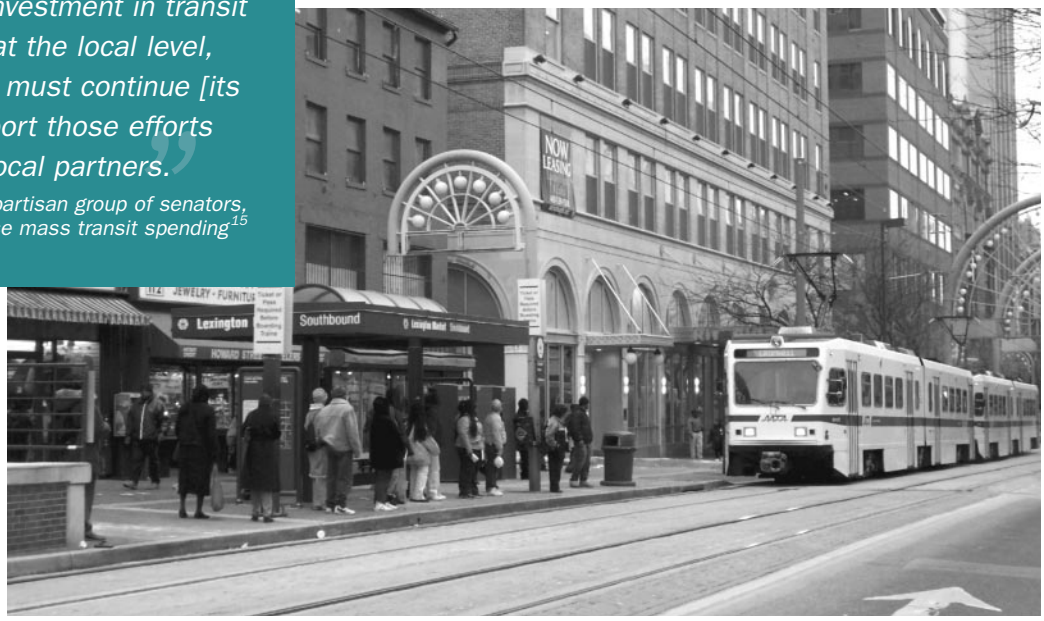
12. Senators urge Bush administration to provide resources for public transit systems; Congress set to reauthorize transit and highway programs in 2003. Available at: http://www.tea3.org/news.asp?id=28. Accessed February 4, 2003.

13. The growing smart legislative guidebook: model legislation threatens opportunity. Available at: http://www.demographia.com/db-grsmart.htm. Accessed March 3, 2003.

14. Reason online: free minds and free markets. Interview with Peter Gordon. Available at: http://reason.com/9806/fe.gordon.shtml. Accessed March 3, 2003.

15. New Jersey Future 2003: a checklist for smarter growth in 2003. Available at: www.njfuture.org/newsletter/2003q1.pdf. Accessed March 3, 2003.

> *"Communities across America…have stepped up to the plate by funding transit at record levels. At a time when the demand for increased investment in transit is so clearly evident at the local level, the federal government must continue [its commitment] to support those efforts of our state and local partners."*
>
> *—Letter signed by a bipartisan group of senators, urging President Bush to increase mass transit spending*[15]



Courtesy of Office of Smart Growth, Maryland Department of Planning.

Light rail in Baltimore, Md.

CENTERING Suburbia

How One Developer's Vision Sharpened the Focus of a Community

Doug Spohn on Duluth's newly created Town Green. Photos courtesy of Catherine Staunton.

| Rachel J. Wilson

METRO-ATLANTA–BASED developer Doug Spohn operates his development firm around a simple theory about human nature: if given the opportunity, people will gravitate toward activity and social interaction and, therefore, a better quality of life. Spohn's latest development project has provided him with the perfect testing ground for his theory. In 1998, Spohn was asked to help transform a sprawling Atlanta suburb into a centered, healthy community. Along with several key community members and the local government, Spohn has turned parking lots and decrepit buildings that once loosely represented downtown Duluth, Ga, into an open-air stage upon which neighbors can connect with each other, opt to burn calories instead of gasoline, and ground themselves within their community. In planning this transformation within the heart of Duluth, Spohn was resolved to tackle several key health issues associated with urban growth, including the health of the environment and both the physical and emotional health of all community members, regardless of their demographics.

FADING TRADITION

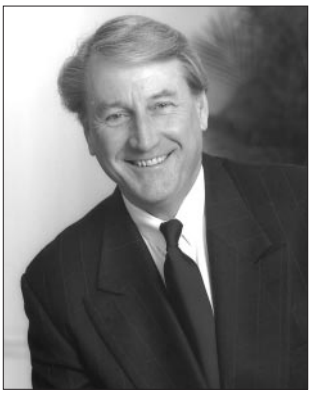
Located 25 miles northeast of Atlanta in Gwinnett County, Duluth covers 9.8 square miles and has an ethnically and economically diverse population of more than 22 000. The city's commercial and corporate corridor is among the county's busiest; more than 1600 businesses are based within Duluth's city limits. Originally, the Duluth area was home to Cherokee Indians. The city was officially chartered in 1876 and was one of the first to be established within Gwinnett County.

Although Duluth has a rich history and small-town charm, because of its proximity to Atlanta, it fell victim to the urban sprawl that so often accompanies population growth. Within the past few decades, as more metro-Atlanta residents began to move further away from the Atlanta city limits, Duluth came to typify the sprawling suburb: extensive roads, homogeneous neighborhoods, and strip malls built to the specification of stringent and inflexible zoning laws. The shift in land-use patterns in Duluth resulted in increasing dependence on the automobile and consequently in such negative effects as a deteriorated and economically depressed downtown area, the creation of an urban heat island (i.e., an increase in temperature caused by an abundance of asphalt and a lack of green space), lower water and air quality, and more car crashes and injuries. Duluth residents were at increased risk for the adverse physical and psychological effects of urban sprawl.

MOVING TOWARD THE PAST

Working hand in hand, Duluth residents and the local government formed the Downtown Development Committee, vowing to put the brakes on the suburban momentum that was so negatively affecting their community. Duluth needed revitalization to provide its residents a renewed sense of community pride. Spohn was contacted by the city of Duluth in 1998. He was the ideal addition to the team of residents and politicians who wanted to see downtown Duluth turn around. Not only did he have more than 30 years of experience in developing local land for residential and mixed use, but he had a unique vision that set him apart from most metro-Atlanta developers.

"In planning this transformation within the heart of Duluth, Spohn was resolved to tackle several key health issues associated with urban growth, including the health of the environment and both the physical and emotional health of all community members, regardless of their demographics."



Doug Spohn, progressive developer.

Spohn already had been operating with the health of homeowners and the environment in mind, developing neighborhoods that provided residents with ample recreation options, from walking to visit neighbors on shaded sidewalks to exercising in designated green-space areas. When the city contacted Spohn, the timing was right; he had become frustrated at county zoning ordinances that had restricted him from placing green space where it was most needed, from building a park where it would most benefit a community's residents, and from using parcels of land for both commercial and residential purposes.

"Barriers in government prevent smart growth. Most zonings stifle creativity because they are very prescriptive," says Spohn, adding that restrictive zoning ordinances can handicap developers interested in promoting the health of a community. The opportunity to collaborate with the local government and to be granted more flexibility in his community design sparked his interest in the Duluth project.

In planning for the new Duluth, Spohn considered many factors. As a 5-year member of the Atlanta Regional Commission's Environmental and Land Committee, Spohn is knowledgeable about the complex environmental health issues surrounding a population shift to the suburbs; encouraging smart growth to help clean up the environment was one of his primary concerns. One of the most complex issues that would need to be addressed was the use of automobiles. Dependence on motor vehicles for transportation substantially contributes to many negative human and environmental health effects; however, in transforming the heart of Duluth, Spohn maintained realistic expectations for the future.

"Through his work in Duluth, Spohn strives to "raise the bar" for other developers who might consider making similar changes to other existing downtown areas."

"[Americans] are likely never going to get rid of the car—especially those who live in the suburbs," says Spohn. He realized early on in his planning that the best way to reduce the adverse effects of automobiles was to create a city that would decrease overall driving time. "Atlanta still leads the nation in the number of miles driven per person per day, at 35 miles," he notes. "If you took 2 miles off of that, Atlanta would comply with the Clean Air Act; if you cut the 35 miles in half, the [environmental degradation] process would be reversed tremendously. This is my goal."

Driving time to Atlanta could be cut by creating "nodes," or townships, within a suburban area that provide additional options for work and leisure. Spohn comments that "It makes a lot of sense for products and services to be located in nodes, because it creates a shorter drive and therefore increases the quality of air and decreases stress levels." For example, driving could be reduced if people walked or drove a short distance to theater events instead of driving 20 miles to attend a downtown performance. Creating nodes would also make public transit a more viable option. Because his ultimate goal was to encourage Duluth residents to walk or bicycle instead of drive, the city also had to plan for alternative, walkable and bikeable routes and make existing roads more pedestrian and cyclist friendly.

The way in which land is used also affects the health of the environment. Leaving plenty of green space would be key to the success of Spohn's plans; increasing tree canopy and replacing asphalt with grassy parks reduces the environmentally detrimental heat-island effect. Making the downtown Duluth area appealing for home buyers is also critical in maintaining water quantity; revitalizing an existing community allows water taps and sewers to be reused instead of abandoned and reduces the need for additional water systems. According to Spohn, in as few as 30 years, metro-Atlanta builders will likely be restricted from creating communities that would require new water taps.

Spohn also made the health of Duluth residents a priority in his plans. He knew that in designing the downtown Duluth area, he and his fellow Downtown Development Committee members would need to create a backdrop that would provide residents with connectivity—a place where people of all ages and cultural backgrounds could work, play, and live. Traditional zoning ordinances would have no place in such a town; residential and commercial property would need to intermingle. The new downtown would need to be filled with activity, a place that would tempt locals to walk or bicycle to the town's center instead of driving to a suburban shopping mall. The heart of Duluth would need to be accessible to its residents; sidewalks would have to be poured and streets modified to slow traffic and accompany a new, more active lifestyle. The emotional health of the community also took center stage in the plans. Scheduled social events and performances would motivate residents to venture outdoors and reconnect with their neighbors. In addition, restaurants with outdoor seating, kid-friendly water fountains, and unique retail stores would entice people to the town center.

BUILDING SUCCESS

In the fall of 2000, ground was broken, the first step in moving Duluth back to the "village atmosphere" so vital to improving the health of the community. Now, more than 2 years later, the first phase of the project has

been completed. The heart of Duluth now consists of a 5-acre Town Green, a grassy area upon which locals can relax or play. A large fountain is located toward the center of the Green, providing an area for both reflection and recreation. One end of the Green is bordered by a street, which, despite being heavily traveled, has now been made more pedestrian friendly by being paved with a raised brick pedestrian walkway to prevent drivers from traveling at excessive speed.

At the other end of the Green, a terraced amphitheater serves as a community gathering place. Unique retail stores, restaurants with outdoor seating, and lofted homes were built around the Green in a style reminiscent of the past, reminding locals of the city's history. The most striking building on the Green is a teahouse that also houses small retail and commercial businesses. Built in 1901, the teahouse was originally a private home. When Spohn undertook the Duluth project, the building had become dilapidated and subdivided into 4 rental units. One of Spohn's first priorities was to refurbish the turn-of-the-century home, which would become the city's architectural anchor.

Because parking is often limited in downtown areas, the success of the businesses located on the Green and of the overall village concept hinges on accessibility by local patrons. Walking to the Town Green is only possible if sidewalks are available. Although most newer subdivisions in the Duluth area were built with sidewalks, they ended at subdivision entrances, taking homeowners, according to Spohn, "nowhere." Therefore, through Gwinnett County's Special Purpose Limited Option Sales Tax (a tax that provides millions of dollars for the creation of sidewalks, bicycle paths, and other community-friendly projects), extensive sidewalks have been made available to residents who opt to walk rather than drive to the Town Green. Even more sidewalks will be added to connect neighborhoods to the downtown area as they are needed.

Although more downtown Duluth development is planned for the future, Spohn already can see the rewards of his work on a daily basis. His development company, Spohntown Inc, is now based in the second story of the teahouse facing the downtown Town Green. He needs only to look out of his office window to see his success: teenagers gathering after school at the old-fashioned soda fountain, toddlers running in and out of the fountain on a summer day, and many locals enjoying being outdoors and catching up with neighbors. Spohn is not the only one looking. "Here you see people of all sizes and backgrounds sitting and watching children play and taking in the architecture and fresh air," he remarks. By 2005, the atmosphere originating in the Town Green area will radiate outward even further, as more neglected buildings are given a facelift and additional green space is planted.

Spohn credits the city of Duluth, local residents, and Gwinnett County for much of the project's success. Duluth residents organize a fall festival each year, the proceeds of which go directly toward paying off the debt for the construction of the village amphitheater, and the city of Duluth funded the construction of the Town Green. Gwinnett County historically has worked hard to purchase land for recreation purposes, creating a precedent for the downtown Duluth transformation. According to Spohn, in the last 5 years, Gwinnett has done an "enviable job" of creating both "passive" and "active" parks. In addition, the state-funded Neighbor Woods Program, operating through the county's Clean and Beautiful Board, has already been instrumental in coordinating the planting of more than 3000 trees since 2000.

ASPIRING TO A MODEL COMMUNITY

Other developers have indicated an interest in Spohn's project since ground was broken more than 2 years ago. Through his work in Duluth, Spohn strives to "raise the bar" for other developers who might consider making similar changes to other existing downtown areas. "My hope is that if other developers could do 80% of what I have done in Duluth, we will all benefit," he says. However, he admits that taking on such a project can be challenging for developers, because getting financing for unconventional development projects is difficult. In general, lenders feel safer funding projects that keep with tradition; however, that tradition is now characterized by sprawl. Spohn was fortunate to obtain funding from a lender that was familiar with his previous projects and willing to take a risk.

Spohn also realizes that the new Duluth "works" because demand for commercial buildings and for homes is greater than the supply. He encourages the city of Duluth to hire an independent, third-party consultant to evaluate absorption rates because, in Spohn's words, "the worst thing a city could do is try to make decisions regarding growth based on opinion." He cautions other developers against the mind-set that "bigger is better," noting that Duluth residents regularly voice appreciation of the city's intimacy.

The success of the Duluth project has inspired Spohn to plan the transformation of other suburban areas into more independent townships in the future. Although critics have called the creation of metro townships a fad, Spohn could not disagree more. His development of downtown Duluth has helped restore the tradition that a century ago united the community. It has also given the city's residents a renewed sense of pride that will keep them anchored to their town, resulting in a lasting vitality. ■

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Health, Morality, and Housing: The "Tenement Problem" in Chicago

In this article, I trace the history of Chicago's Health Department, exploring when and how housing conditions came to be considered a serious social problem requiring municipal regulation. Although journalists and labor leaders were among the first Chicagoans to link tenement housing to the spread of contagious disease, Health Department officials quickly began regulating the city's housing stock under their own authority. I argue that in attempting to eliminate the dangers of contagious disease, a long-standing public health threat, health officials drew new attention to the dangers of multifamily dwellings and set a precedent for government regulation of living conditions in tenement dwellings.

Margaret Garb, PhD

IN 1876, JUST WEEKS AFTER being appointed commissioner of Chicago's newly established Department of Health, Oscar Coleman De Wolf announced several new policies to fight disease in the city. First, he called for sanitary inspectors to inspect meat at the slaughterhouses and confiscate any that was tainted. Chicago's food processors, particularly those connected with the expanding and increasingly hazardous animal-slaughtering and meat-packing industries, proved powerful opponents. Over the following 4 years, De Wolf battled the packers in the courts and fought their representatives in the City Council, finally winning passage of a fairly weak and largely unenforceable law requiring meat inspections.[1]

Few complaints were heard, however, about De Wolf's other initiative: regular inspections of the city's tenements. As thousands of European immigrants flowed into the city seeking jobs in rapidly expanding manufacturing enterprises and packing houses, tenement inspections became the city's leading tool for protecting public health. Throughout the 1880s, health inspectors entered and examined the homes of the immigrant poor and working classes, establishing a government presence in ordinary people's lives.

Reactions to De Wolf's initiatives reveal much about power relations and politics in an industrializing city and help to shed new light on the strategies of the nascent public health movement. An aggressive and ultimately unsuccessful effort to limit the spread of disease, De Wolf's tenement inspection program was initiated during a period of laissez-faire capitalism, amidst increasingly hostile conflicts between labor and capital over working conditions in the city's factories. Long before local, state, and federal governments asserted their authority to regulate wages, hours, working conditions, or the dumping of slaughterhouse waste in the city's waterways, the Chicago Department of Health secured legislation and public approval for regulating the rental dwellings of the urban poor. In a city where government regulations of property rights were minimal at best, De Wolf effectively redefined property rights in housing and removed the "tenement problem" from other issues of conflict between workers and their employers. Shifting from scientific to social to moral explanations for the presence of disease in the city, De Wolf designated tenements a health problem open to government regulation. Tenement inspections provided the new field of public health with the stamp of legal authority.

Epidemic disease was a serious and widely feared problem in 19th- and early 20th-century cities. De Wolf could confidently assert a public interest in regulating both tenements and tainted meat. Tenements, which De Wolf defined as any building in which 3 or more families resided in separate households, typically lacked indoor plumbing and often housed several families in a few tiny rooms. During the 1880s, growing numbers of immigrant

wage laborers crowded into the 2- and 3-story wood frame or brick buildings that lined dusty, unpaved streets within walking distance of the factories west of the Chicago River and surrounding the slaughterhouses just south of the city limits. Living conditions in many of the city's tenements did endanger the health of residents. Diphtheria, typhoid, cholera, smallpox, and yellow fever regularly appeared in working-class neighborhoods.[2] But as sanitary reformers battled employers, such as those in the meat-packing business, urban housing—and tenements in particular—emerged as a central arena for legitimizing the public health movement.[3]

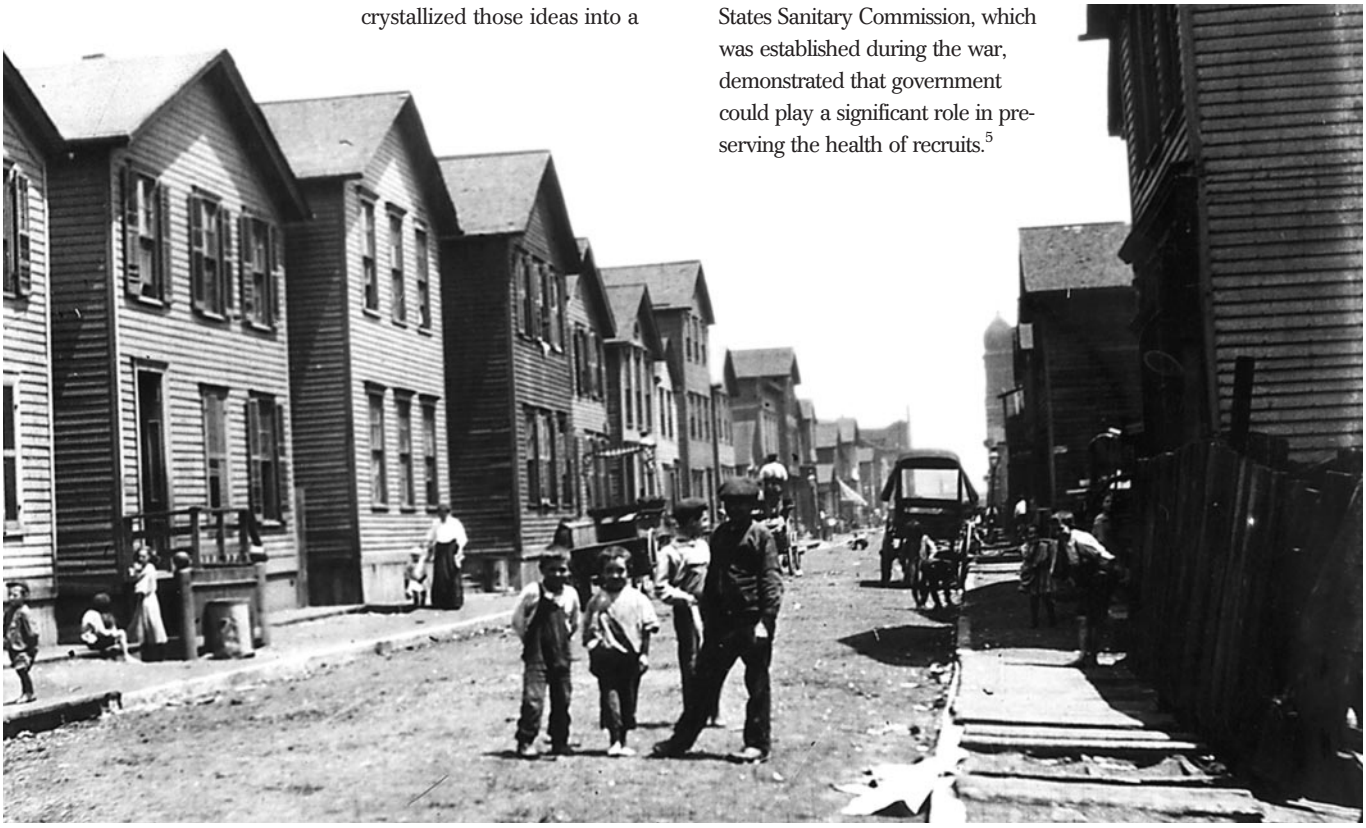
THE RISE OF SANITARY REFORM

De Wolf was in most ways typical of the physicians who joined the late-19th-century sanitation movement. He was born in 1835 and raised in western Massachusetts, where his father, Thaddeus K. De Wolf, practiced medicine for 62 years and participated in a local temperance movement. Oscar De Wolf studied with his father and then, beginning in 1856, attended a 2-year course at the Berkshire Medical College in Pittsfield, Mass, before heading to New York and later to France for further study. When the Civil War began, De Wolf returned to the United States and was appointed assistant surgeon of the First Massachusetts Cavalry; he later became surgeon for the Second Massachusetts Cavalry.[4]

De Wolf's training in New York City and in France may have brought him in contact with many of the ideas that would influence the emerging field of public health. His service during the Civil War, however, probably crystallized those ideas into a more practical form. For many of the physicians who served in the Union Army, wartime experience significantly altered their views of their profession and of medicine's relationship to government.

The war was the nation's largest and most devastating medical event of the 19th century. Outbreaks of disease in military camps permanently changed the medical profession's conception of the causality of disease. Many physicians, who watched as thousands of recruits died from diseases associated with poor sanitation in army camps, left the service with a new appreciation for sanitation and hygiene. Their experiences during the war seemed to demonstrate that disease could strike even the best of men; disease was not a moral but a "sanitary" problem. The war sparked unprecedented involvement in medical matters by government. The work of the United States Sanitary Commission, which was established during the war, demonstrated that government could play a significant role in preserving the health of recruits.[5]

Children playing in the streets near the stockyards, Chicago.



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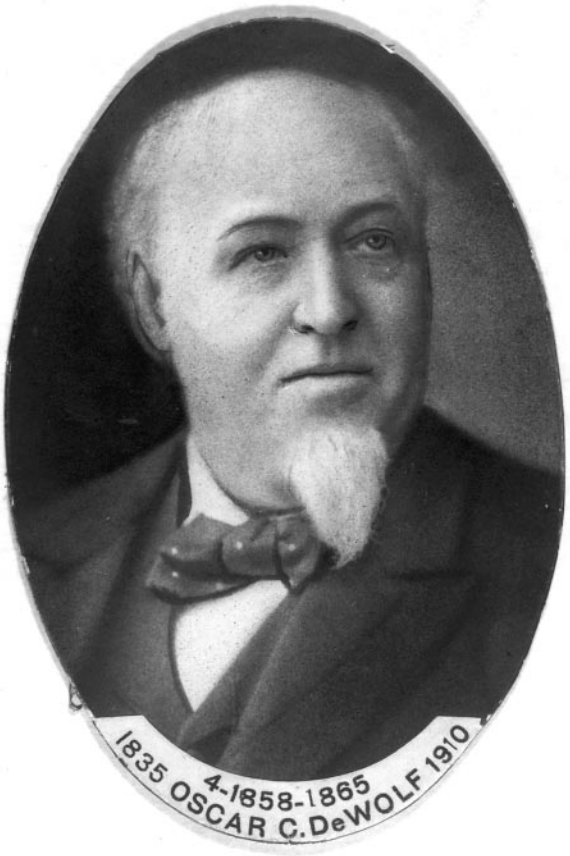

Oscar C. De Wolfe (1835-1910).

"In 1889, the Chicago Inter-Ocean *wrote of De Wolf, 'When he took charge of the office it could hardly be called a department of health. It had neither form nor comeliness and was doing nothing in the way of sanitary work except keeping a registry of the deaths.' The newspaper added, 'The department has since developed into the most active and efficient health service in the United States.'"*

By the 1880s, physicians, horrified by wartime experiences and influenced by new theories about disease causality emerging from Europe, were launching health reform efforts in several American cities. In 1866, New York City established the nation's first municipal health department, which became a model for health departments in cities across the country. On the heels of the mid-1860s cholera epidemic and under pressure from a growing number of citizens' sanitary associations, cities like Baltimore, Pittsburgh, and St Louis, along with the state of Massachusetts, established boards of health. Although sanitary reformers continued to push for health regulations, many urban health boards were active during periods of disease outbreaks but languished for lack of funding and lack of clear legal authority through much of the 1870s and 1880s.

The Massachusetts Board of Health, possibly the most effective in the country in the 1870s, regulated slaughterhouses and launched a series of investigations into tenement conditions. Chicago also established a municipal health board in the 1860s, under the leadership of John Rauch, who in the days and weeks following the fire of 1871 organized health services and worked to provide clean water, food, and housing for the 112 000 people left homeless by the fire.[6] When the city's leaders turned their attention toward rebuilding Chicago's commercial center, however, the Board of Health was largely overlooked until 1876, when De Wolf was appointed to run the reorganized Department of Health.[7]

De Wolf was 42 when he was appointed Chicago's health commissioner. In his nearly 13 years in office, he established a national reputation as a leader in the public health movement. In 1882, the British Association for the Advancement of Science made De Wolf an honorary member. A year later, he received the diploma of the Society of Hygiene of France. On his death in 1910, the *Journal of the American Medical Association* remarked that De Wolf "had achieved national prominence in sanitary matters."[8]

Like health department officials in New York, De Wolf used his position to create a professionalized bureaucracy to supervise Chicago's health. De Wolf transformed the Department of Health from a small semiofficial entity into a firmly established agency within the city's government. In 1889, the *Chicago Inter-Ocean* wrote of De Wolf, "When he took charge of the office it could hardly be called a department of health. It had neither form nor comeliness and was doing nothing in the way of sanitary work except keeping a registry of the deaths." The newspaper added, "The department has since developed into the most active and efficient health service in the United States." Under De Wolf's command, the department's staff increased from 1 physician, an assistant commissioner, 2 secretaries, 2 meat inspectors, and 13 untrained sanitary inspectors to nearly 50 inspectors and physicians in 1889. In 1877, the department's budget stood at $36 640, excluding amounts designated for scavenger service and dead animal removal, representing a little less than 9 cents per capita for general health work.[9] By 1885, the department received a total appropriation of $240 460, includ-

ing $171 383 for scavenger work and removing dead animals. Since the city's population had grown rapidly, hitting 664 000 in 1885, the department's per capita expenditure for health-related work increased to just over 10 cents per person. By then the Department of Health had the second largest budget in city government.[10]

De Wolf's aim was not merely to establish the newly specialized field of public health but also to create areas of specialization within the field. Possibly using New York's Health Department as his model, he divided his staff among various specialty areas. There were medical inspectors, sanitary policemen, meat inspectors, and tenement and factory inspectors, as well as a physician managing a smallpox hospital on the city's west side. Each unit of inspectors was supervised by a manager who worked directly under De Wolf, and each was expected to produce a yearly report of its activities.[11]

De Wolf's methods for preventing the spread of contagious disease represented a transitional period in medical science and in the field of public health. In the 1880s, a new field of medicine, bacteriology, emerged from the discovery of the cholera vibrio by a German physician, Robert Koch. Similar, independent experiments by Louis Pasteur in Paris had demonstrated decisively that disease was caused by microorganisms, not dirt. Several Chicago researchers were among the first in the United States to publicize the new germ theory of disease. Courses on germ theory were introduced into the city's medical school curricula in the mid-1880s.[12]

De Wolf, apparently ambivalent about rejecting the older views, gradually introduced germ theory to public health work. While he continued to promote sanitary measures, such as the expansion of the city's sewer system and regular cleaning of privy vaults, his agency helped shift the focus of public health practice from a primary concern with the cleanliness of the urban environment to the diagnosis and prevention of specific diseases. By 1888, De Wolf had declared that diphtheria was "not a filth disease, but an infectious disease, like smallpox." By then he had already published a paper on Asiatic cholera in which he mentioned Pasteur and asserted that the disease was caused by bacteria. In the essay, published in 1885, De Wolf wrote, "It is not probable that the cholera poison is wafted about in the atmosphere except in a very limited extent."[13]

The gradual incorporation of bacteriology into public health measures initially prompted renewed efforts to identify disease and prevent its spread. De Wolf established new and more rigorous requirements for reporting all varieties of disease. His yearly reports to the City Council included an array of statistics covering all causes of death and all outbreaks of disease, carefully listed by each sufferer's age, nationality, and residential district.[14]

TENEMENT INSPECTIONS AS PUBLIC HEALTH PRACTICE

Most importantly, De Wolf launched a program of tenement inspections, the first in the city's history, sending Health Department inspectors to examine "interiors" of tenements. In 1877, health inspectors examined 200 tenement buildings, finding just 4 "which could possibly be rated as fairly perfect, *i.e.* they did not violate any of the sanitary laws *in force at that date* [italics in original]." That year, inspectors examined rented dwellings only, but the program was expanded the following year to include "all classes of habitable buildings, upon a written request from the owner, agent, or occupant of such buildings." De Wolf also sought to send inspectors into multifamily rental buildings without a request, or even permission, from the property owner. As a history of the department's work published in the 1886 Health Department Report recounted, that move prompted some opposition; at least one City Council member derided De Wolf's efforts and claimed that the health commissioner was driven by "fanaticism."[15]

De Wolf's programs, marking the initial steps of the urban sanitary movement, illustrate the tangled history of municipal governance and public health.[16] He established tenement and factory inspections before gaining explicit legal authority to regulate housing and working conditions. When packing house owners launched a full-blown assault on his meat inspection program, De Wolf wrote a letter to the *Chicago Tribune*, commenting that "While I fully appreciate the necessity of additional laws, I must add that it is in my judgment absolutely impossible for the public officers in this country to contend successfully with great financial interests unless sustained by active organizations of good and patriotic citizens."[17] That support would not appear for another 25 years.

Tenement inspections, however, proved a less controversial approach. To demonstrate the

need for full inspections of tenements, De Wolf, in 1879, appointed a voluntary corps of 30 physicians to survey all tenement dwellings in the city. With that report in hand, he appeared before the City Council and urged it to pass a "tenement housing ordinance." He noted that "Incessant, systematic and searching inspection from house to house and street by street, from January to January, can alone prevent the growth of sanitary evils, which when matured and in full force, are beyond the control of men."[18] By then his program of tenement inspections had gained support from nearly all quarters of the city. The Citizens Association, a civic reform organization led by Marshall Field and George Pullman, 2 of the city's leading businessmen, campaigned for tenement inspections, as did the *Progressive Age*, the city's leading labor newspaper, and the city's voice for the Republican Party, the *Chicago Tribune*.[19]

Still, builders and landlords objected when the City Council approved the city's first housing ordinance in 1880. The law granted the Health Department the right to inspect and regulate sanitary conditions in places of employment and in tenement dwellings. It required property owners to remove all stench-causing refuse and to provide tenement residents with containers for garbage. Builders and landlords, complaining of the additional costs, challenged the city government's right to regulate private property. Claiming that a man "should have complete jurisdiction" over his property, landlords urged the City Council to repeal the ordinance.[20]

With landlords refusing to comply with the municipal ordinance, the Illinois General Assembly, under pressure from sanitary reformers, labor, and business leaders, passed the state's first Tenement and Factory Ordinance on May 30, 1881. The law put the sanitation and construction of all tenements, workshops, and lodging houses under the supervision of the Chicago Department of Health. Building owners quickly responded to the legislation by placing new clauses in rental contracts, stating that the tenant accepted the residence in its existing condition. According to most leases, the tenant was responsible for maintaining the dwelling to conform to the law.[21]

De Wolf sent inspectors throughout the city's wage-laboring neighborhoods, citing tenants for violations of the law and sometimes forcibly removing them from their homes. As De Wolf noted in a speech before the state medical society, sanitary inspections represented the "police authority" in tenement districts. The "incessant and systematic searching" for disease was performed by former policemen who personified the department's authority in the streets and dwellings of the city's laboring classes. Sanitary inspectors were granted the same "powers" as "regular police," with an additional power: "the power to enter any house without a search warrant between the hours of sunrise and sunset." Moreover, the sanitary police were authorized to forcibly remove those suffering from smallpox to the city's smallpox hospital.[22]

By 1887, the department's tenement inspections had the full support of the law. Inspections were widespread and, in De Wolf's view, "thorough." In that year, health inspectors examined 31 171 occupied dwellings. Of these, 7702 were rented single-family dwellings with the inspections made at the request of the owner or occupant.[23] An additional 2557 buildings under construction were examined, with inspectors typically making 2 or 3 visits to construction sites. Inspections involved examinations of "heating, lighting, ventilating, plumbing and drainage arrangements therein." In 1887, inspectors issued 13 855 citations, some for multiple offenses in a single dwelling. Remedies for these violations included "defective plumbing repaired," the construction of new sewers and drains, "ventilation applied to waste and soil pipes," the cleaning of privy vaults, "rooms limewashed, leaky roofs repaired, uninhabitable basements cleared of inhabitants, filthy yards cleaned," and the cleaning of unoccupied grounds. In 1887, the Health Department filed 251 "suits against persons neglecting or refusing to provide the improvements demanded under the law." The courts, according to the department's report, ruled on the side of the Health Department in every case but two. In the few cases brought to the appeals courts, the lower courts' rulings in favor of the Health Department were sustained.[23,24]

THE BURDEN OF HEALTH REGULATIONS

Although the state law seemed to place responsibility for conforming to Health Department regulations on property owners, landlords quickly shifted the costs onto tenants. With regulations issued in the 1880s, the Health Department sought to establish minimal standards for health and safety in new construction, putting the burden of compliance on the building own-

ers.[25] In existing buildings, however, department inspectors could do little more than cite tenants for violations of the Health Department codes. When the law specified that landlords bear the costs of sanitary ordinances, property owners often shifted the financial burden onto tenants. When property owners whose buildings were on streets with sewers were required to connect the buildings to the sewers, for example, they typically made the connections and then, when the lease was up, raised rents to cover the additional capital costs of sewer hookups and indoor plumbing. Indoor plumbing did enhance health and property values, but often at an additional cost to the tenants.

Some landlords simply forced tenants to pay all assessed fees on the rented homes. Walter L. Newberry, who owned scores of residential properties around the city and rented to skilled craftsmen and middle-class families, added new clauses to lease agreements in 1881, requiring tenants to pay property taxes, water taxes, and sewer connection fees. If the buildings were located on streets lacking sewers, Newberry's leases stated that tenants must keep "outhouses, and washbasins in sanitary condition in accordance" with city ordinances. Newberry further protected himself with a clause stating that a Board of Health citation "shall be, among other things, conclusive evidence [among] the parties hereto of the breach of this covenant." With rents running as high as $25 per month, Newberry's properties were priced beyond the means of unskilled laborers.[26]

It is not clear how ordinary people responded to the arrival of sanitary inspectors in their homes. The city's English-language newspapers, including the labor press, supported tenement inspections and apparently published no accounts of tenants refusing entrance to the inspectors. Still, the inspectors faced some resistance. Health Department reports from the 1880s generally include comments about the 2 or 3 households each year that refused entrance to the sanitary inspectors. In most cases, regular police were called, the homes were forcibly inspected, and sick residents were forcibly removed. Remarkably, this authority faced no legal challenges until 1922.[25,27] Sanitary inspections likely incited some ethnic hostility among the city's recent immigrants. The inspectors were predominantly Irish, charged with entering and inspecting the homes of recently arrived Polish, Greek, Italian, and Eastern European families.

De Wolf was aware of the potential for ethnic conflict between inspectors and tenement dwellers. Administrative control of the sanitary inspectors became a point of conflict—possibly the only conflict—between De Wolf and Mayor Carter Harrison. Harrison, whose immense charisma and masterly control over the distribution of patronage jobs yielded him 5 terms in office, personally hired all sanitary inspectors. Harrison was born in Kentucky and claimed to be a descendant of a signer of the Declaration of Independence. In a city that regularly voted Republican in national elections, Harrison, a Democrat, put together a diverse coalition to win election. He was, as Richard Schneirov notes, "a broker between most of the city's organized interest groups," including middle-class reformers, business moderates, German socialists, and Irish immigrants. But the mayor's power was rooted in the city's Irish neighborhoods. In the 1880s, the Irish were not the largest of the city's immigrant groups, but they were among the most vocal and politically active, a powerful force in the Democratic Party since the 1850s. By 1865, one

View from the rear of the Maxwell Street settlement, Chicago.

third of Chicago's police were Irish, and in the 1880s, under the patronage of Mayor Harrison, the Irish gained an even greater proportion of the coveted jobs. Sanitary inspectors, hired from the police force, were predominantly Irish. Despite De Wolf's repeated complaints that the system was tainted by politics, Harrison refused to relinquish control of even a slice of the city's patronage jobs to the health commissioner.[28]

The inspection procedures illustrate the distinction drawn between the property rights of tenement dwellers and those enjoyed by people living in single-family dwellings. While health inspectors regularly entered tenement dwellings without warrants or court orders, they also made "special examinations" of dwellings occupied by single families, but only at the request of physicians, occupants, or owners. "This class of work was not at first intended to form a part of the 'regular' work of the inspectors," De Wolf announced in 1882. But, he added, since "the public generally are recognizing the true value and benefit to health of perfect house sanitation" the department was willing to inspect single-family dwellings and "suggest proper remedies for all defects found." In most cases, these inspections were made "as a last resort" by the occupant seeking relief from odors or poor construction.[29]

No single area of the city was targeted for inspections, but the single-family homes of the city's elite were excluded. The department's report for 1885 noted that inspections covered every area of the city, "except those classed as strictly 'residence' streets of the most expensive and thoroughly improved character." Because Health Department inspectors entered single-family houses only at the request of the occupant or owner, neighborhoods with large numbers of multifamily rented dwellings were more likely to be inspected than areas lined with single-family, owner-occupied dwellings. As the department's report for 1885 commented, "The method adopted was to apply the entire working force of inspectors to the most insanitary localities first, following this with the next most urgent localities, and so on to the end of the work. . . ."[30]

Neighborhood scene with geese, Chicago.

EXPLAINING THE "TENEMENT PROBLEM"

De Wolf's reports to the City Council illustrate his analysis of the link between tenement dwellings and public health. He attributed the most intractable tenement conditions to immigrant families. His descriptions of tenement dwellings provided an elaborate social map of the city's residents and reinforced categories separating social groups. In De Wolf's view, the national origin of the occupants determined the sanitary conditions of tenement dwellings. Native-born Americans lived in "well-furnished" flats; Germans occupied tenements that were "comfortably built, but having less of the so-called modern conveniences." De Wolf blamed the inferior quality of the tenements occupied by Italian, Polish, and Bohemian immigrants on a mix of custom and biology. He wrote, "There are a great many old buildings in this city which are unfit for habitation by civilized people, yet they are inhabited, and generally by Italians, Poles, Bohemians, and others, who, in their trans-Atlantic homes have been accustomed to live in crowded quarters." De Wolf added that it was difficult to enforce tenement ordinances "against such habitual and hereditary unsanitary modes of living." Since these immigrants rarely understood Health Department regulations, they required "constant watching" by sanitary inspectors."[31]

But De Wolf did not believe that the residents' nationality was the sole source of the tenement problem and the consequent spread of disease in the city. He also highlighted the residents' status as low-wage workers. Here, he treated the city's working classes as a singular group, never noting that native-born and German workers tended to congregate in higher-skilled and better-paying jobs, thus enabling them to afford more comfortable housing. While nationality might determine living conditions, it did not, in De Wolf's view, correspond to differing levels of wages or employment opportunities. De Wolf contended that a growing class of permanent wage workers unable to purchase or rent a single-family dwelling rendered tenement housing inevitable. Without "proper" housing, wage workers would, in De Wolf's view, remain the source of the city's health problems. De Wolf's views proved an exaggeration; nearly one fourth of the city's wage laborers, most of whom were immigrants, owned some real estate in 1880. Still, De Wolf wrote that "the whole number of occupants of tenement houses is about equal to the foreign population, not because of their nationality, but because it is wage workers of all nationalities who are compelled to occupy tenement houses."[32]

The city's labor leaders agreed with this explanation—De Wolf's second—for the city's "tenement problem." But labor leaders took the argument a step further. Since the 1870s, labor leaders had asserted that higher wages would help workers improve their housing conditions. Housing, and in particular a workers' ability to set aside some money toward the purchase of a house, was part of what organized labor termed "an American standard of life," and central to labor's larger agenda. In a July 1881 call for a citywide strike, the *Progressive*

Age conflated the "evils" of employers with those of landlords, urging workers to strike "against the growing spoilations *[sic]* through rents, profits, commissions, pools, speculations and peculations of the miscalled middle classes. . . ."[33] To the city's labor press, wages and working and housing conditions were intimately entwined.

De Wolf was well aware of the rumblings from the city's nascent labor movement. By the early 1880s, Chicago had become the headquarters of the nation's socialist and anarchist movements and a center of strength for the more moderate Knights of Labor. Even as De Wolf's inspectors were roaming the tenement districts, unions associated with the Trades and Labor Assembly were holding regular meetings on the city's south and west sides. More significantly, some of the city's labor activists worked with the sanitary reform movement, seeking to use health regulations to improve living and working conditions for the city's working classes. Mayor Harrison had looked to the Health Department to reconcile his diverse and often conflicting coalition of supporters. This coalition had forced the mayor to reorganize the city's Health Department and to include at least one out-spoken socialist factory inspector, Joseph Gruenhut. A Bohemian-born labor activist and columnist in the *Progressive Age*, Gruenhut regularly attacked both employers and landlords, arguing that higher wages and home ownership opportunities were the keys to improving wage laborers' living conditions and public health. For Gruenhut, an American "standard of life" included "better homes, less burdensome toile, and more agreeable conditions of labor," along with higher wages.[34]

Although the Health Department was not empowered to legislate wage levels for the city's laborers, a perceived link between housing conditions and wages appeared in the department's yearly reports. The reports featured lengthy tables listing the wages and hours for most of the city's trades and commercial workers. Summarizing the information, chief tenement and factory inspector W. H. Genund commented in his 1886 report that workers appeared to be achieving their long-standing goal of working shorter hours "without reducing the daily wages paid therefore." He also noted that women earned 25% to 50% "less than the wages of men employed in the same trade or occupation," and, without expressing an opinion on the disparity, added that "general superintendents draw annual salaries reaching far into the thousands of dollars."[35]

Although Health Department reports implied that low wages and seasonal employment were linked to inadequate housing for wage laborers, De Wolf did not support labor's demands for higher wages or shorter working hours. A vocal and often controversial advocate for tenement and factory inspections, De Wolf, unlike some of his staff, distanced himself from labor's demands for higher wages. Instead, he began to advocate for the construction of "model tenements," a solution first proposed in London and later promoted in New York in the 1840s. The "unpleasant fact," De Wolf wrote, was "that practically no provisions are being made to house the toiling multitude of wage-workers in our city." Those willing to construct rental housing for wage workers would not be expected to forgo a profit. Pointing to the success of the community of Pullman, built by George Pullman just south of the city, De Wolf argued that the construction of "blocks of tenement houses on the most approved plans for the wage working poor" could prove "highly profitable."[36] De Wolf, of course, could hardly foresee the violent conflict that would erupt in Pullman a decade later.

Woman mending by a window in a Chicago slum dwelling.

Working with volunteers from the Citizens Association, the Health Department in 1884 conducted a 9-month survey of all tenement dwellings. The association's Committee on Tenement Housing was more direct than the Health Department's assertions. Remarking on recent conflicts between labor and capital, the com-

mittee's report argued that the construction of model tenements would "be a long stride in the direction of a general movement to bring capital and labor into closer economic union."[37] No one came forward to test this thesis by building model tenements. With this strategy, however, De Wolf and the Citizens Association effectively divorced the tenement problem from what many in the late 19th century called the "labor problem": the growing demands of wage workers for higher wages and control over working conditions.

Despite his success in establishing tenement inspections in law and bureaucratic practice, De Wolf failed in another arena that was arguably equally threatening to the public health. His efforts to prohibit the sale of adulterated meat and to bar the packing houses from dumping animal waste in the Chicago River prompted widespread resistance from the city's packers. That resistance campaign, combined with the election of DeWitt C. Cregier, a Democratic rival of Harrison, resulted in the new mayor firing De Wolf in 1889.[38]

HEALTH DEPARTMENT'S RETREAT FROM REGULATION

Tenement inspections continued after De Wolf's departure. In the 1890s, however, the sanitary reform movement began to crumble and party politicians, rather than health reformers, ran the department. As one settlement house worker commented, health inspectors, loath to anger "friends of the neighborhood politicians," refused to condemn "unsanitary tenements."[39] By 1894, the department's chief inspector for the Bureau of Sanitary Inspection, Andrew Young, took just 6 pages in a 268-page report to discuss sewage, drainage, light, and air in the city's homes. Much of the rest of the report featured graphs of morbidity and mortality rates for the city's residents, reports on efforts to improve the quality of milk and meat sold in the city, and reports on conditions in the city's factories. Despite growing acceptance of the germ theory of disease, Young offered a complex, and slightly convoluted, explanation of the cause of disease, reviving the old formula of linking immorality with poor health. "The fact is clear to us that crime is begotten by sin, and sin begotten by disease, disease begotten by filth and filth begotten by ignorance and neglect of the individual or the inefficiency of the agencies employed by the municipality to correct such conditions." Yet in his view, the municipality and its Health Department were hardly inefficient. "So beneficial have been their [health inspectors'] operation that to-day the bath and toilet rooms of our hotels and residences are the altars of cleanliness, luxurious in their appointments, tasteful in every detail and construction."[40]

While some settlement house workers asserted that low wages and irregular employment were directly linked to the inadequate shelter and poor health of many urban workers, Young glossed over possible causes for the city's death rate. He instead asserted that "Health is wealth. Sickness in a community breeds demoralization, vice and crime, and adds to the burdens borne by the citizen and the community at large." Housing reformers, who launched a 9-month study of tenement conditions 5 years later, were surprised to learn that the "bath and toilet" rooms in the homes of large numbers of impoverished Chicagoans were either nonexistent or in dangerously defective condition.[41]

Even in the 1880s, close inspections of tenement districts and surveillance of tenement residents had hardly abated the problem of disease. There were no major epidemics under De Wolf's watch, but mortality rates from disease remained fairly steady. However, a precedent had been set. When settlement house workers took up the cause of public health and tenement reform in the 1890s, they effectively used the tenement and factory legislation to pressure the City Council to enforce sanitary regulations. They also pushed for the passage of new and stricter housing legislation.

But De Wolf's tenement inspections had other, possibly unintended consequences. As De Wolf expanded the reach of the Health Department and its inspectors, property rights in the family home increasingly were conceived as rights that adhered only to owner-occupied, single-family dwellings. Under legislation passed in 1880 and 1881, tenement dwellings were placed in a legal category that included factories and workshops and excluded single-family houses.[42] Tenement dwellings were open to inspection and regulation in ways that owner-occupied or rented single-family houses were not. Landlords' efforts to enhance their profits by forcing tenants to maintain their housing according to Health Department regulations further strained the budgets of tenement residents. Although De Wolf could confidently assert a public interest in ridding Chicago of disease, he ultimately placed the burden of health regulations on those least likely to challenge his authority, tenement residents.

At the same time, De Wolf maneuvered between scientific, social, and moral explanations for the tenement problem to establish the legitimacy of public health work and legal authority for his interventions in the homes of the urban poor. His strategic use of tenement inspections to bolster the authority of the Health Department helped to separate struggles for improved housing from conflicts between labor and capital. De Wolf designated housing a health problem, one that could be solved by government regulations or the commercial construction of model tenements.

De Wolf's focus on the links between the national origins of residents and their living conditions obscured the economic issues at the heart of the "tenement problem." While articulating a public interest in regulating tenements, De Wolf helped to shift the focus of the city's housing and health reformers from Chicago's evolving and complex class system to the realm of ethnic, and later racial, taxonomies. Certainly, concern with sanitation was part of a genuine effort to improve the health of the city's residents. But De Wolf's rhetorical blending of racial hierarchies and scientific analysis of the threat of disease emanating from tenements permitted propertied Chicagoans to avoid investing capital in improving tenement dwellings or raising wages so that laborers could afford better housing, and it provided them with pseudo-scientific justifications for regulating the immigrant poor.[43] ■

About the Author

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Endnotes

1. Seizures of condemned meat did increase from 85 950 pounds in 1873 to 1991164 pounds in 1893, but the *Chicago Tribune* complained throughout the late 1870s and 1880s of inadequate inspections and issued regular reports of people sickened by tainted meat. See Bessie Louise Pierce, *A History of Chicago*, vol 3, *The Rise of the Modern City, 1871–1893* (New York: Alfred A. Knopf, 1957), 322; *Chicago Tribune*, October 22, 1879, 8; and *Chicago Tribune*, October 27, 1879, 4.

2. See Chicago Department of Health reports for the 1880s; Christine Meisner Rosen, *The Limits of Power: Great Fires and the Process of City Growth in America* (New York: Cambridge University Press, 1986), 173; E. Robinson, *Robinson's Atlas of the City of Chicago, Illinois* (New York: Robinson, 1886); Pierce, *Rise of the Modern City*, 50–56; and Richard Sennett, *Families Against the City: Middle Class Homes of Industrial Chicago, 1872–1890* (Cambridge: Harvard University Press, 1984), 25–39.

3. Much excellent scholarly work has been produced on the late 19th century's sanitary reform movement. While earlier work celebrated the achievements of the sanitarians, some of the more recent work argues that sanitary reform work contained elements of social control. Historians looking at the history of social medicine and immigration highlight the nativist strain in sanitary reform; others spotlight the sanitarians' utilitarian strategies to improve labor's productivity by improving worker health. My aim is to highlight the significance of tenement inspections in sanitary work and to explore the ways public health efforts functioned to redefine property rights in housing. See, for example, John Duffy, *The Sanitarians: A History of American Public Health* (Urbana: University of Illinois Press, 1992); Alan M. Kraut, *Silent Travelers: Germs, Genes, and the "Immigrant Menace"* (Baltimore: Johns Hopkins University Press, 1994); Judith Walzer Leavitt, *The Healthiest City: Milwaukee and the Politics of Health Reform* (Madison: University of Wisconsin Press, 1996); Barbara Gutmann Rosenkrantz, *Public Health and the State* (Cambridge: Harvard University Press, 1972); and Martin V. Molosi, *The Sanitary City* (Baltimore, Md: The Johns Hopkins University Press, 2003).

4. *The Pittsfield Republican*, 1906; *Dictionary of American Medical Biography*, ed. Howard A. Kelly and Walter L. Burrage (Boston: Milford House, 1971), 324–325; *Journal of American Medical Association* 54 (1910): 1229; James C. Russell, *History of Medicine and Surgery and Physicians and Surgeons of Chicago* (Chicago: Biographical Publishing Corporation, 1922), 100.

5. James H. Cassedy, *Medicine in America: A Short History* (Baltimore: Johns Hopkins University Press, 1991), 64–65.

6. Duffy, *The Sanitarians*, 120–124, 140–150; Rosenkrantz, *Public Health and the State*, 52–54; Chicago Council Proceedings, 1876–1877, 16, 111; *Bulletin of the Society of Medical History of Chicago* (Chicago: The Society, 1911–1948), 89–104. Rauch was a former lieutenant colonel and surgeon in the Union Army and a founding member of the American Public Health Association.

7. Pierce, *Rise of the Modern City*, 320.

8. *The Pittsfield Republican*, 1906; *Journal of the American Medical Association* 54 (1910): 1229.

9. Isaac D. Rawlings, *The Rise and Fall of Disease in Illinois* (Springfield, Ill: Schepp & Barnes, Printers, 1927), 327; *Chicago Inter-Ocean*, July 23, 1889; Pierce, *Rise of the Modern City*, 320–323.

10. *Report of the Department of Health for the City of Chicago for the Year 1885* (Chicago: George K. Hazlitt & Co, Printers, 1886), 122.

11. See Department of Health reports for 1876–1889.

12. Thomas Neville Bonner, *Medicine in Chicago: 1850–1950, A Chapter in the Social and Scientific Development of a City* (New York: Stratford Press Inc, 1957), 25–26; Erwin H. Ackerknecht, *A Short History of Medicine*, rev ed (Baltimore: Johns Hopkins University Press, 1982), 177–178; Donald L. Miller, *City of the Century* (New York: Simon & Schuster, 1996), 430; Cassedy, *Medicine in America*, 76–86.

13. Oscar C. DeWolf, *Asiatic Cholera: A Sketch of Its History, Nature, and Preventive Management* (Chicago: American Book Company, 1885), 9.

14. Cassedy, *Medicine in America, 78; Reports of the Department of Health for the Years 1877–1889* (Chicago: George K. Hazlitt & Co, Printers, 1890).

15. *Report of the Department of Health for the City of Chicago for the Year 1886* (Chicago: George K. Hazlitt & Co, Printers, 1887), 47–49.

16. Even before De Wolf's appointment, the city comptroller, arguing that the health board had exceeded its legal authority in hiring sanitary inspectors, refused to pay the sanitary inspectors. When the board sued the city, the case was decided in its favor, but only after several years of battles among city officials over expenditures for health-related activities. The appellate courts ruled that the statute establishing the board had broad powers, including the hiring of sanitary inspectors. See "The People of the State of Ill. ex. rel. H.W. Jones," in *Reports of Cases at Law and in Chancery Argued and Determined in the Supreme Court of Illinois*, vol 45, ed. Norman L. Freeman (Chicago: E. B. Myers and Company, 1869), 297–301. Similarly, De Wolf's initial efforts to regulate the slaughtering industry were challenged in court, with the courts ruling that the commissioner did not have the legal authority to issue such regulations. See "Charles H. Tugman v. The City of Chicago," in *Reports of Cases of Law and Chancery* (Springfield, 1876), 405–412.

17. *Chicago Tribune,* October 22, 1879, 8.

18. *Report of the Department of Health of the City of Chicago for the Year 1879–80* (Chicago: George K. Hazlitt & Co, Printers, 1881), 22. Pierce, in *Rise of the Modern City* (p. 54), asserts, "Not until 1880 did a municipal ordinance give the Department of Health the right to inspect and regulate sanitary conditions even in places of employment." But, according to the board's yearly reports, sanitary inspectors were inspecting tenement housing as early as 1875.

19. *The Progressive Age*, October 1, 1881, 4, and March 5, 1881, 2; *Chicago Daily Tribune*, Sept. 20, 1874.

20. Chicago City Council Proceedings, 1881 and 1882, 25. Quoted in Pierce, *Rise of the Modern City*, 54.

21. Walter L. Newberry Estate, Financial Records, Newberry Library Collection. Newberry owned scores of houses and multifamily dwellings, which he rented to skilled laborers.

22. *Report of the Board of Health of the City of Chicago for the Years 1874 and 1875* (Chicago: Bulletin Printing Co, 1876), 91.

23. "Report of the Tenement and Factory Inspectors," in *Report of the Department of Health of the City of Chicago for the Year 1887* (Chicago: M. B. Kenny, Printer, 1888), 55–56.

24. *Report of the Department of Health for the Years 1876–1877* (Chicago: Clark & Edwards, Printers, 1878), 70–73.

25. Construction regulations also generated opposition. De Wolf noted that many builders, resisting the Health Department's regulations, seemed "to think that the law should leave them to construct buildings entirely of their own ideas." As New York's tenement reformer, Robert W. DeForest, would note 2 decades later, legislation designed to regulate construction on private property seemed to run counter to the most fundamental ideals of American liberty: "Most of us have been brought up to believe that, as owners of real estate, we could build on it what we pleased, build as high as we pleased, and sink our buildings as low as we pleased. Our ideas of what constitutes property rights and what constitutes liberty are largely conventional." *Report of the Department of Health for 1887*, 6; *The Tenement House Problem, Including the Report of the New York State Tenement House Commission of 1900*, ed. Robert W. De Forest and Lawrence Veiller (New York: Macmillan Company, 1903), 84.

26. Walter L. Newberry Estate, Financial Records, Newberry Library Collection.

27. "The People ex rel Jennie Barmore, Relatrix, vs. John Dill Robertson et al Respondents," in *Reports of Cases at Law and in Chancery*, vol 302 (Springfield, Ill: 1922), 422–436.

28. Richard Schneirov, *Labor and Urban Politics: Class Conflict and the Origins of Modern Liberalism in Chicago, 1864–97* (Chicago: University of Illinois Press, 1998), 88–89; Miller, *City of the Century*, 441–449; *Report of the Department of Health for the City of Chicago for the Years 1883/1884* (Chicago: George K. Hazlitt & Co, Printers, 1885).

29. *Report of the Department of Health of the City of Chicago for the Year 1882* (Chicago: George K. Hazlitt & Co, Printers, 1883), 6.

30. *Report of the Department of Health for 1885*, 72.

31. *Report of the Department of Health for 1882*, 47–48.

32. *Report of the Department of Health for 1882*, 47.

33. *The Progressive Age*, July 23, 1881, and October 8, 1881.

34. Schneirov, *Labor and Urban Politics*, 89, 147–148.

35. *Report of the Department of Health for 1886,* 74–77.

36. Elizabeth Blackmar, *Manhattan for Rent, 1785–1850* (Ithaca: Cornell University Press, 1989), 207–212; *Report of the Department of Health for*

1883/1884, 21–22. Pullman boasted that since the town was completed in 1881, not a single case of cholera, typhoid, or yellow fever had been reported. Miller, *City of the Century*, 225; *The Rights of Labor*, April 1893, np.

37. Robert Hunter, *Report of the Committee on Tenement Houses of the Citizens Association of Chicago* (Chicago: Geo. K. Hazlitt & Co, Printers, 1884), 7.

38. *Chicago Tribune*, April 19, 1889, and May 23, 1889; Pierce, *Rise of the Modern City*, 364–366. Cregier was elected with the support of organized labor, some socialists, and urban reformers. Gruenhut, the tenement inspector, had written much of the Democratic Party's platform and kept his job with the Health Department after the election. It is not entirely clear why Cregier forced De Wolf out, but the *Chicago Tribune*, admittedly anti-Cregier, suggests that the new mayor distributed jobs to his labor supporters; Schneirov, *Labor and Urban Politics*, 280–283.

39. Howard Eugene Wilson, "Mary E. McDowell and Her Work as Head Resident of the University of Chicago Settlement House, 1894–1904," unpublished dissertation, University of Chicago, 1927, 36–37.

40. *Annual Report of the Department of Health of the City of Chicago for the Year Ended December 31, 1894* (Chicago, 1895), 183–189; Wilson, "Mary E. McDowell and Her Work," 94–95.

41. *Annual Report of the Department of Health for 1894*, 188; Hunter, *Report of the Committee on Tenement Houses*, 3.

42. In 1884, the New York Court of Appeals had ruled that a law banning cigar making in a tenement dwelling violated the cigar makers' rights to labor. The court's decision, based on the freedom to contract for work, similarly placed the tenement in a legal category that linked it to production and separated it from the single-family home. See "In re Application of Paul" (no number in original), Court of Appeals of New York, 94 NY 496, 1884 (Lexis 293).

43. For a fuller discussion of the shift from class to ethnic and racial analysis of health problems, see, for example, *Degeneration: The Dark Side of Progress*, ed. Sander Gilman (New York: Columbia University Press, 1985); Gilman, *Difference and Pathology: Stereotypes of Sexuality, Race and Madness* (Ithaca: Cornell University Press, 1985); and Nancy Stepan, "Race and Gender: The Role of Analogy in Science," *Isis* 77 (June 1986): 261–277.

Promoting Safe Walking and Biking to School: The Marin County Success Story

Catherine E. Staunton, MD, Deb Hubsmith, BS, and Wendi Kallins, BA, for the Marin County Bicycle Coalition's Safe Routes to School Program

Walking and biking to school can be an important part of a healthy lifestyle, yet most US children do not start their day with these activities.

The Safe Routes to School Program in Marin County, California, is working to promote walking and biking to school. Using a multipronged approach, the program identifies and creates safe routes to schools and invites communitywide involvement. By its second year, the program was serving 4665 students in 15 schools.

Participating public schools reported an increase in school trips made by walking (64%), biking (114%), and carpooling (91%) and a decrease in trips by private vehicles carrying only one student (39%).

WALKING AND BIKING TO school provide a convenient opportunity to incorporate physical activity into a child's daily routine, yet only about 1 US child in 9 starts the day by walking or biking to school. About one third of children take a bus to school and half are driven in a private vehicle.[1] Increasing the proportion of children walking and biking to school are 2 of the national health objectives for 2010.[2]

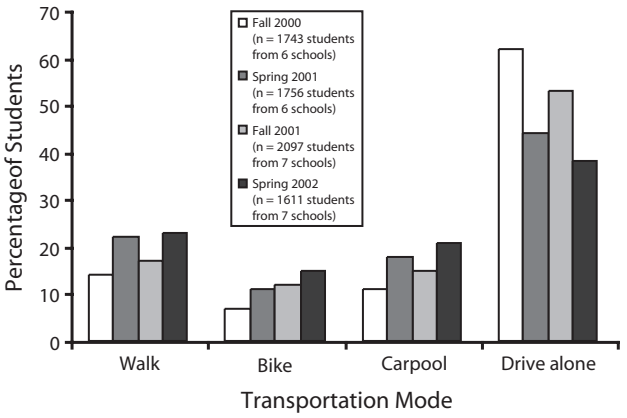
THE PROGRAM

Marin County is a middle- and upper-class community on the California coast just north of San Francisco. Its population of 247 707 includes about 35 000 school-aged children.[3] In 1999, 2 local residents began working to increase the number of Marin County children walking and biking to school and to decrease the number of school trips made by private vehicles. By 2000, the Marin County Safe Routes to School Program, initially funded by a grant from the Marin Community Foundation, had been established. In August 2000, the program received a $50 000 grant from the National Highway Traffic Safety Administration. During the 2000–2001 school year, the program served about 3500 students in 9 schools (7 public and 2 private); by the 2001–2002 school year, 4665 students in 15 schools (12 public and 3 private) were enrolled; in the 2002–2003 school year, 7609 students in 21 schools (17 public and 4 private) are participating. Enrolled schools include elementary and middle schools.

The program has only 4 paid staff. One of the 2 founding members is the program director, and the other works several hours a week supervising and promoting the program. A full-time educator is employed to develop the program's school curriculum and oversee classroom education. A traffic engineer assists in identifying and creating safe routes for participating students. A private consulting firm, hired during the second year, oversees and evaluates the program. The Marin County Safe Routes to School Program relies heavily on parent, teacher, and community volunteers to carry out its broad range of activities (Table 1). The program requires each school to identify a volunteer team leader prior to enrolling.

During the first 2 years of the program, modes of school transportation were determined by student surveys. For 3 consecutive days in the fall, prior to the start of the program, and then again in the spring, prior to the end of school, volunteers visited classrooms and, using a show of hands, asked children to indicate the transportation mode they used in traveling to school that morning. Results from the 3 days were averaged. Because the survey relied on inexperienced volunteers, results were often incomplete; some schools did not conduct the surveys at all and other schools did not survey all classrooms. Six of 9 schools participated in the fall 2000 and spring 2001 surveys. Seven of 15 schools participated in the fall 2001 and spring 2002 surveys.

By spring 2002, more than $1 million in additional funding had been received, including dona-



Note. A "carpool" is defined as 2 or more students per private vehicle, and "drive alone" is 1 student (with driver) per private vehicle.

FIGURE 1—Transportation choices in the public schools participating in the Marin County Safe Routes to School Program, 2000–2002.

tions from local foundations, local businesses, and grants from the Marin Community Foundation, Marin County, the City of San Rafael, and the California Departments of State Services and Transportation. Funding for the 2002–2003 school year is expected to exceed $2 million. Much of this funding is earmarked for infrastructure changes (Table 1) to decrease the traffic danger faced by students walking and biking.

EVALUATION

The student transportation surveys (Figure 1) reveal an increase in walking, biking, and carpooling in the participating public schools during the first 2 years of the Marin County Safe Routes to School Program. From fall 2000 to spring 2002, there was a 64% increase in the number of children walking, a 114% increase in the number of students biking, a 91% increase in the number of students carpooling, and a 39% decrease in the number of children arriving by private car carrying only one student.

The data in Figure 1 include 6 schools for the first school year and 7 for the second school year. Only 2 schools participated in surveys both years. Analysis restricted to these 2 schools produced results similar to those in Figure 1 (data not shown). School bus trips are not shown because only 2 schools offered bus transportation. Of the 3 private schools, data were collected in only 2 of the schools and only during the second year of the program. These 2 private schools, with a total of 401 students (data not included in Figure 1) drawn from larger geographic areas than in the public schools, recorded only modest increases in walking (1%) and carpooling (5%) and small decreases in biking (–1%) and "drive alone" transport (–4%). As discussed below, improved and expanded program evaluation is planned.

DISCUSSION

The Marin County Safe Routes to School Program provides a successful model for promoting safe walking and biking to school. Decreased rates of walking and carpooling and increased rates of "drive alone" in fall 2001 may be secondary to the addition of new schools, lack of program activities over the summer, or both. The program is making an important difference to participating communities by enhancing health, reducing traffic congestion, and helping build a greater sense of community. Although barriers to walking and biking to school, such as distance, traffic danger, crime, and the availability of volunteers, will vary by community, many aspects of this program will be useful to other interested communities.[4] Efforts to create safe and accessible routes for children to walk and bike to school can facilitate safe walking and biking for people of all ages.

NEXT STEPS

The program, now in its third year, has maintained its base curriculum while planning an expansion to recruit more schools, including high schools. Future goals include expanding and perfecting data collection and analysis by using professional statisticians. Further analysis could include evaluating the effectiveness of the individual program activities, analyzing transporta-

Lagunitas School students get help from a volunteer crossing guard.

TABLE 1—Activities of the Safe Routes to School Program: Marin County, California, 2000–2002

Mapping Safe Routes to School

- Town-wide programs established to identify and create safe routes for walking and biking to each school.
- Volunteers walk the routes and report findings to the group documenting routes for their school.
- Findings pooled on a master map.
- Solutions to make walking and biking safer are designed (sidewalks, improved pedestrian signage and crossings, a pedestrian bridge, extension of existing bike trail, bike lanes, etc.).
- Funds for needed traffic infrastructure changes are obtained through grant applications, public presentations leading to donations, and local government funds.

Walk and Bike to School Days

- All schools participate in "International Walk to School Day" (beginning of October); many schools also have scheduled monthly or even weekly "Walk to School Days."
- Many schools provide drinks and treats to children walking or biking to school.
- "Staging Areas" are established where students who live too far away can be dropped off and then walk the rest of the way to school.
- Some schools also encourage children to take school buses rather than travel by private vehicle.

Frequent Rider Miles Contest

- Children are issued "tally cards" with 20 possible points per card.
- Children earn 2 points for walking or biking and 1 point for taking the bus or carpooling.
- At 20 points, children get a small prize and can enter a raffle for larger prizes.
- Children are encouraged to submit multiple cards for the raffle during the contest period.

Classroom Education

- Safety training is provided through videos, discussions, presentations, and hands-on "bicycle rodeos." A "toolkit," developed by the program and available to all participating schools, includes curriculum guidelines for teaching pedestrian and biking safety.
- Using age-appropriate, local examples, children were taught about transportation choices and the environment, physical activity for health, the power of community involvement, and the interrelatedness of all species and habitats.
- In one middle school, children produce their own videos on "the role bicycles play in our society."

Walking School Buses and Bike Trains

- Organized groups of children that walk and bike together are called "walking school buses" and "bike trains," respectively. These groups allow parents to share the responsibility of supervising children's trips and provide the children with a group of friends to travel with.
- Geographic mapping systems showing the homes of the participating children facilitate establishment of these walking and biking groups. Some schools posted these geographic maps along with parent contact information to facilitate formation of "walking school buses" and "bike trains."

Newsletters and Promotions

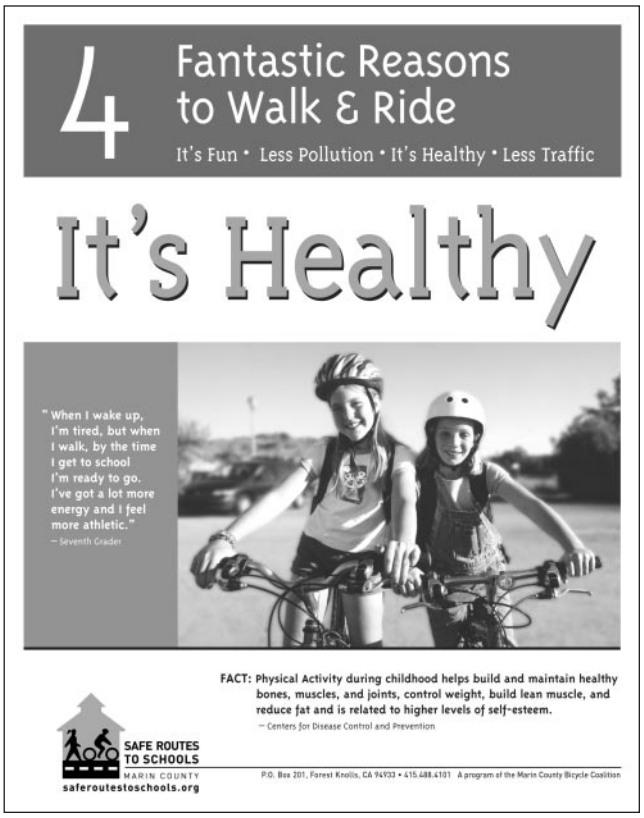
- Throughout the year, the volunteer team leaders at each school are supplied with template flyers, fact sheets, posters, and newsletters (newsletters are also mailed to elected officials, town staffers, and other interested parties).
- Local newspapers have run feature articles about the program.
- The program uses an e-mail listserv, an e-mail distribution list, and a Web site (see "Resources").
- An annual countywide forum is held to welcome new schools to the program and allow participating teams of volunteers at all schools to meet and talk with one another.

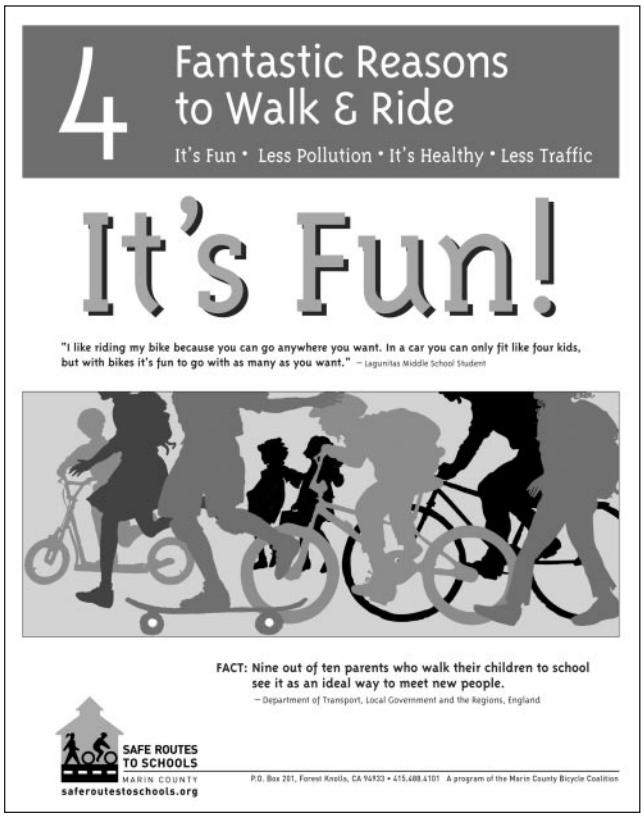
Networking and Presentations on the State and National Level

- Safe Routes to School staff have been invited speakers at numerous state, national, and international conferences.

KEY FINDINGS

- Marin County's Safe Routes to School Program has been successful in promoting walking and biking to school.
- Much of the program's success can be attributed to the contributions made by parents, teaches, and community volunteers.
- This community-based program also led to an increased rate of carpooling to school and a substantial drop in the use of private vehicles for transporting students to school.





Promotional posters made and used by the Marin County Safe Routes to School program.

tion modes by travel distance, assessing health outcomes such as improved physical fitness, having closer surveillance for travel-related injuries, measuring changes in traffic congestion, and using comparison communities. ■

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Contributors

C.E. Staunton reviewed the study design, research methods, and data analysis and then wrote the report. D. Hubsmith and W. Kallins, who founded and continue to run the Marin County Safe Routes to School Program, were central in collecting and analyzing the data presented in the report and also reviewed the report.

Acknowledgments

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References

1. *Our Nation's Travel: 1995 NPTS Early Result Report.* Washington, DC: US Dept of Transportation; 1997. Publication FHWA-PL-97-028.

2. *Healthy People 2010: Understanding and Improving Health.* Washington, DC: US Dept of Health and Human Services; 2001.

3. US Census Bureau. State and county quick facts. July 2001. Available at: http://quickfacts.census.gov/. Accessed January 7, 2003.

4. Centers for Disease Control and Prevention. Barriers to walking and biking to school—United States, 1999. *MMWR Morb Mortal Wkly Rep.* 2002; 51:701–704.

Resources

- Marin County Safe Routes to School. Available at: http://www.saferoutestoschools.org/.
- "Kids Walk-to-School" Program. Available at: http://www.cdc.gov/nccdphp/dnpa/kidswalk/resources.htm.
- Walk to School Day USA. Available at: http://www.walktoschool-usa.org.
- International Walk to School Day. Available at: http://www.iwalktoschool.org.
- National Highway Traffic Safety Administration. Available at: http://www.nhtsa.dot.gov/people/injury/pedbimot/ped/saferouteshtml/toc.html.
- National SAFE KIDS Campaign. Available at: http://www.safekids.org/tier3_cd.cfm?folder_id=183&content_item_id=3410.

Community Gardens: Lessons Learned From California Healthy Cities and Communities

Joan Twiss, MA, Joy Dickinson, BS, CHES, Shirley Duma, MA, Tanya Kleinman, BA, Heather Paulsen, MS, and Liz Rilveria, MPA

Community gardens enhance nutrition and physical activity and promote the role of public health in improving quality of life. Opportunities to organize around other issues and build social capital also emerge through community gardens.

California Healthy Cities and Communities (CHCC) promotes an inclusionary and systems approach to improving community health. CHCC has funded community-based nutrition and physical activity programs in several cities. Successful community gardens were developed by many cities incorporating local leadership and resources, volunteers and community partners, and skills-building opportunities for participants.

Through community garden initiatives, cities have enacted policies for interim land and complimentary water use, improved access to produce, elevated public consciousness about public health, created culturally appropriate educational and training materials, and strengthened community building skills.

THE COMMUNITY GARDEN IS exceptional in its ability to address an array of public health and livability issues across the lifespan.[1] Community gardens began at the turn of the 20th century and had a renaissance during the world wars in response to food shortages.[2] Today, community gardens appeal to newly arrived immigrants, who use them to help maintain cultural traditions, and to those committed to sustainability and to personal and family health. Populations with health disparities, who do not always have access to nutritious-food outlets (e.g., grocery stores, farmers' markets) owing to limited financial and community resources and inconvenient transportation systems, can usually access these gardens, since they often are located within neighborhoods and on public property.

Community gardens build and nurture community capacity, which Mayer defines as "the sum total of commitment, resources, and skills that a community can mobilize and deploy to address community problems and strengthen community assets."[3] Strong community capacity increases the effectiveness and quality of community health interventions.

Public health professionals often lament the fact that much of their work is out of the public eye. Community gardens are a tangible way to demonstrate public health efforts through organized community-centered activities that link many disciplines. Professionals outside of mainstream public health often become new allies as a result of their involvement. Community gardening fosters neighborhood ownership and civic pride, which in turn build a constituent base for a broader policy agenda.

Since 1988, California Healthy Cities and Communities (CHCC) has supported over 65 communities with developing, implementing, and evaluating programs, policies, and plans that address the environmental, social, and economic determinants of health. Consistent with the Healthy Cities and Communities Model, CHCC program participation requires the convening and ongoing support of a broad-based collaborative, including the public, nonprofit, business, and resident sectors; development of a work plan with community-driven priorities and strategies; and the commitment of the municipality, demonstrated by a council resolution and the dedication of staff time and other resources.[4,5] Several cities have established community gardens, often building on past healthy community initiatives.

In general, participating California Healthy Cities (Table 1) that established community gardens responded to a request for proposals to improve community nutrition and physical activity, or to enhance food security. Each city's approach is unique to its circumstances. Funding is provided through grants from CHCC (a program of the Center for Civic Partnerships/Public Health Institute) (Table 2). Significant technical assistance is also provided to local coordinators and collaboratives by CHCC staff and its partners.

TABLE 1—Demographics of Cities That Received Grants From California Healthy Cities and Communities for Community Garden Programs

City (County)	Population[a]	Race/Ethnicity,[a] %	Median Household Income,[a] $
Berkeley	102 743	White, 55.2	44 485
(Alameda)		Asian/Pacific Islander, 16.4	
		African American, 13.3	
		Hispanic/Latino, 9.7	
		Native American, 0.3	
		Other, 0.6	
Escondido	133 559	White, 51.9	42 567
(San Diego)		Hispanic/Latino, 38.7	
		Asian/Pacific Islander, 4.6	
		African American, 2.0	
		Native American, 0.6	
		Other, 0.1	
Loma Linda	18 681	White, 47.1	38 204
(San Bernardino)		Asian/Pacific Islander, 24.5	
		Hispanic/Latino, 16.3	
		African American, 7.0	
		Native American, 0.3	
		Other, 0.2	
Oceanside	161 029	White, 53.6	46 301
(San Diego)		Hispanic/Latino, 30.2	
		Asian/Pacific Islander, 6.6	
		African American, 5.9	
		Native American, 0.4	
		Other, 0.1	
San Bernardino	185 401	Hispanic/Latino, 47.5	31 140
(San Bernardino)		White, 28.9	
		African American, 16.0	
		Asian/Pacific Islander, 4.4	
		Native American, 0.6	
		Other, 0.2	
West Hollywood	35 716	White, 81.4	38 914
(Los Angeles)		Hispanic/Latino, 8.8	
		Asian/Pacific Islander, 3.8	
		African American, 2.9	
		Native American, 0.2	
		Other, 0.2	
California	33 871 648	White, 46.7	
		Hispanic/Latino, 32.4	
		Asian/Pacific Islander, 10.9	
		African American, 6.7	
		Native American, 1.0	
		Other, 16.8	47 493

[a]Based on 2000 census data.

KEY ELEMENTS FOR SUCCESS

While each city's approach was unique, the following key elements were integral to their efforts: commitment of local leadership and staffing, involvement of volunteers and community partners, and availability of skill-building opportunities for participants.

Local Leadership and Staffing

A city's commitment of staff, financial, and in-kind resources is critical to the success of community gardens. City councils in each of 2 cities purchased land valued at $70 000 or more for gardens, one using funds from the Community Development Block Grant, the other using money from the city's general fund. Both provide staffing on an ongoing basis.

Volunteers and Community Partners

The participation and support of diverse community members help a community garden to thrive. These members include residents, partner institutions (e.g., schools, county health departments, universities), and volunteers (e.g., businesses, civic associations). The inclusiveness of gardens allows individuals and groups to contribute their knowledge, skills, and experience. The business community contributes tools and lends equipment. Residents and volunteers often identify innovative strategies to leverage resources, such as the interim use of property and volunteer stipends as an alternative to hiring staff.

Skill-Building Opportunities

Gardening workshops provide opportunities for residents, staff, and volunteers of all ages to develop skills in leadership, community organizing, cultural competency, and program planning, implementation, and evaluation. Leadership development is enhanced through experiential learning, which includes intergenerational and peer-to-peer mentoring and train-the-trainer models. Volunteers and staff lead workshops, organize taste-testing events, facilitate discussions, advocate for the garden, and develop culturally appropriate resources (e.g., training materials, cookbooks, newsletters, Web sites). These ongoing, interactive learning opportunities help to sustain momentum for the garden.

RESULTS AND DISCUSSION

Community improvements resulting from gardening efforts can range from knowledge and skill enhancement to behavioral and systems change. California Healthy Cities with community gardens have experienced a wide variety of results (Table 2). For instance, the city of West Hollywood complemented its school gardening program with nutrition and physical activity education. Self-reported survey results demonstrated that participants (n=338) increased the number of physical activity sessions from 4.9 to 5.2 times per week (6%) and increased consumption of fruits and vegetables from 3.44 to 3.78 servings per day (10%). In the city of San Bernardino, the number of students that began gardening at home after participating in the school gardening program increased from 62 to75 (20%).

The city of Berkeley passed the Berkeley Food and Nutrition Policy, which supports small-scale sustainable agriculture (e.g., community gardens, local farms). In

TABLE 2—Characteristics of Community Garden Programs Funded by California Healthy Cities and Communities (CHCC)

City	Lead Department	CHCC Support, $	Funding Sources[a]	Priority Population	Results
Berkeley	Public Health	134 000 (over 5 years)	FFA, Network, TCWF	Youth, ethnically diverse	Established 1 school garden and 1 day care center garden; supported 2 existing school gardens; provided supplies to 3000 gardeners; opened a Farmer's Market in West Berkeley; provided nutrition or physical activity education (or both) to 1800 residents; passed the Berkeley Food and Nutrition Policy.
Escondido	Community Development Block Grant (CDBG)	75 000 (over 3 years)	Network	Ethnically diverse	Established 2 gardens with 218 garden plots involving 600 gardeners; opened a greenhouse to support year-round gardening; passed the "Adopt-A-Lot" policy to encourage the interim use of vacant land for gardens; approved a no-cost water policy for gardens on city property.
Loma Linda	City Manager	38 000 (over 2 years)	DHS	Ethnically diverse	Established 1 garden with 52 plots involving over 40 gardeners. Increased average consumption of fruits and vegetables among 35% of gardeners from 3 to 3.71 servings per day.
Oceanside	Housing and Neighborhood Services	75 000 (over 3 years)	Network	Ethnically diverse	Established 2 gardens involving 85 households; started 2 school gardens involving 115 student gardeners; added 10 plots to a garden serving seniors. Of the 228 residents receiving nutrition education, 86% indicated an intent to improve eating habits.
San Bernardino	Public Services	25 000 (over 1 year)	FFA	Youth, intergenerational, ethnically diverse	Established 3 school gardens involving 127 students; increased the number of students gardening at home by 20%; approved the Vacant Lot Beautification Program that allows public use of private land and city-owned vacant lots to establish gardens or pocket parks.
West Hollywood	Human Services	75 000 (over 3 years)	Network	Youth, intergenerational, ethnically diverse	Established 5 school gardens involving 460 students; designated 2 plots at 2 community gardens for school use; started container gardening programs at 3 schools; increased weekly physical activity sessions from 4.9 to 5.2 times per week and increased consumption of fruits and vegetables from 3.44 to 3.78 servings per day among 338 students participating in gardening and educational workshops.

[a]FFA = Food For All; Network = California Nutrition Network for Healthy Active Families, California Department of Health Services; TCWF = The California Wellness Foundation; DHS = Preventative Health and Health Services Block Grant, California Department of Health Services.

addition, the city of Escondido approved the "Adopt-A-Lot" policy, which allows for the interim use of public and private property for community benefit. This policy provides a special no-fee city permit and an expedited land use approval process that allows normal zoning regulations and requirements (e.g., those concerning parking) to be waived. The policy contributes to city beautification, decreases code violations, and increases space for community gardens.

While each city experienced a variety of results, there were several common lessons learned about the importance of the following:

- ongoing training, mentoring, and leadership development for gardeners and staff;
- building on successful community-based programs through partnerships;
- public awareness of the benefits of community gardens; and
- experiential work (e.g., classes in gardening, exercise, or cooking), which often led to municipal codes and administrative policies.

LOOKING AHEAD

Educating Stakeholders

Informing decisionmakers about the benefits of community gardens can be time-intensive. Changes in leadership can slow momentum. Communicating the benefits beyond the traditional leadership to the community at large can mitigate those challenges, help build a broad-based constituency, and provide long-term, consistent support of community gardening as a norm. Publications, electronic networks, and convenings can support learning across communities.

Integrating Community Gardens Into Development

While the benefits of community gardens are many, land and housing shortages may compete for gardening space. Because community gardens are flexible in their design (e.g., containers on patios and rooftops as options to ground planting), they can be incorporated harmoniously into new structures or into existing facilities (e.g., school campuses, parks, community centers).

Supporting Research

The dearth of data on the positive impacts of community gardens hinders the ability to make a convincing argument when resources (e.g., funding, land, water) are at stake. Anecdotal evidence abounds, but important outcomes such as the physical benefits of gardening and com-

West Hollywood residents tending their garden.

munity connectedness are difficult to measure. User-friendly, multilingual, and adaptable evaluation tools are urgently needed given the diversity of participants and disciplines. The development of strategies to measure the benefits of community gardens would sustain and promote this activity within an active living agenda.

Investing for the Long Term

Given the opportunities and challenges inherent in this work, long-term investments—policymaking, funding, staffing, and acquiring in-kind resources—are needed to support planning, implementation, and evaluation. Community visioning and strategic planning processes are additional opportunities to integrate this work. ■

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Contributors

J. Twiss, S. Duma, and T. Kleinman drafted the original report. J. Dickinson contributed to the original report, researched and contributed to the Results section, developed the tables, and selected the photographs. H. Paulsen drafted the abstract and researched the recommended resources. L. Rilveria researched and formatted the references and resources and contributed to the tables and identification of the photograph. All authors conceptualized and edited the report.

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References

1. Goodman R. Report on community gardening. *Natl Gardening.* May/June 2000:46–49, 53.

2. *New York's Community Gardens—A Resource at Risk.* New York, NY: The Trust for Public Land; 2001.

3. Mayer SE. Building community capacity with evaluation activities that empower. In: Fetterman DM, Kaftarian SJ, Wandersman A, eds. *Empowerment Evaluation: Knowledge and Tools for Self-Assessment and Accountability.* Thousand Oaks, Calif: Sage Publications; 1996:332.

4. Hancock T. Healthy cities and communities: past, present and future. *Natl Civic Rev.* 1997;86:11–21.

5. Twiss J, Duma S, Look V, Shaffer GS, Watkins AC. Twelve years and counting: California's experience with a statewide healthy cities and communities program. *Public Health Rep.* 2000; 115:125–133.

Resources

• Armstrong D. A survey of community gardens in upstate New York: implications for health promotion and community development. *Health and Place.* 2000;6:319–327.

• Center for Civic Partnerships. *Fresh Ideas for Community Nutrition and Physical Activity.* Sacramento, Calif: Public Health Institute; 2002.

• Hancock T. People, partnerships and human progress: building community capital. *Health Promot Int.* 2001;16: 275–280.

• Sallis J, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med.* 1998;15:379–397.

• Active Living by Design. Available at: http://www.activelivingbydesign.org.

• American Community Gardening Association. Available at: http://www.communitygarden.org.

• Center for Civic Partnerships. Available at: http//www.civicpartnerships.org.

The Intersection of Urban Planning, Art, and Public Health: The Sunnyside Piazza

Jan C. Semenza, PhD, MPH, MS

Deteriorating physical features of urban environments can negatively influence public health. Dilapidated environments and urban blight tend to promote alienation and can be associated with social disorder, vandalism, crime, drug abuse, traffic violations, and littering, which in turn affects health and well-being.

In the late 1990s, the Sunnyside neighborhood in Portland, Ore, was plagued by many of these problems. In an attempt to invigorate neighborhood stewardship, the community organized and created a public gathering place; together, they painted a gigantic sunflower in the middle of an intersection and installed several interactive art features.

As a result of these collective actions of "place-making," social capital has increased, thus revitalizing the community, and expanded social networks among residents have stimulated a sense of well-being.

MOST AMERICANS LIVE IN urban areas; 80% live within or in close proximity to a metropolitan area. Physical features of the urban environment influence the way city residents live and work, and they have a direct impact on mobility and social interactions. Some aspects of the urban infrastructure (e.g., water distribution and sewer systems) have dramatically improved public health over the last century; however, other urban planning practices (e.g., the urban grid, single-use zoning) may actually contribute to the epidemics of obesity,[1] diabetes,[2] and depression[3] that are sweeping the United States.

These practices are long-standing. In 1785, Congress passed a land ordinance that prescribed a rectangular grid pattern as the layout for all public lands in the West, which was also applied to the planning of cities and towns.

While this urban design improves efficiency and traffic flow, it is not conducive to social interactions and deprives residents of public gathering places. Zoning rules dictate segregated land use, which has resulted in reliance on the automobile. The resulting poorly designed and maintained neighborhood topography may be associated with physical inactivity[4,5] and depression.[6–9] Urban environments that lack public gathering places and are not zoned for mixed use (both residential and commercial) are not conducive to walking and socializing and thus tend to foster car dependence and isolation.

In this report I describe an innovative and successful community initiative to revitalize the health of a neighborhood, with the goal of revitalizing the health of its residents.

THE PROGRAM

The Sunnyside neighborhood of Portland, Ore, is a moderate-income, urban community with a population of 6513 persons and 3466 households. Most neighborhood residents are White (88%), followed in decreasing order of representation by Asians (4.5%), Hispanics (3.4%), and Blacks (1.7%). Most residents (65%) are renters. In January 2001, a group of residents initiated monthly meetings to devise ways to improve the livability and vitality of the community. During the 9 months of discussions, workshops, design plans, outreach, and block parties that ensued, a new and artistic approach to community-initiated urban development evolved.

A central intersection was designed as a public gathering place: the Sunnyside Piazza (Figure 1). A sunflower, the neighborhood symbol, was selected as the unifying theme of a multiphase plan to enhance social cohesion in the community. The plan included a variety of artistic features intended to reverse urban decay; more importantly, it was anticipated that neighborhood organizing would cultivate social connectedness and a sense of community.[10]

What could have been a formidable challenge to the permitting and approval process was mitigated by the community's decision to involve the City Repair Project (a local nonprofit organization[11]), resident landscape designers and architects, and other community members who brought a modified ordinance (no. 175937) to the city council for approval. In September 2001,

FIGURE 1—Plan for a community gathering place with sunflower design, trellises for hanging gardens, and planters in the parking lanes to prevent parked cars from reducing the visibility of oncoming traffic.

residents embarked on an urban experiment to create a sense of place, identity, and belonging by painting a giant sunflower motif across the intersection (Figure 2). The site was transformed from a busy intersection where streets intersect into a place where people meet.

In May 2002, a second phase was approved by city officials and implemented as part of a community enhancement project: an art wall made of cob (a traditional building material composed of clay, straw, water, and sand) was built with colorful mosaics, shapes, and niches; to facilitate social interactions, a cob information kiosk was installed for the exchange of messages and notices; a solar-powered fountain tiled with glass mosaics was constructed to invite passersby to pause to the sound of running water and to interact with one another (Figure 3).

DISCUSSION AND EVALUATION

Two years after its creation, the Sunnyside Piazza remains a catalyst of sidewalk conversations, as passersby read the signs about the community project, tourists take photographs, children throw pennies into the wishing pond, joggers run an extra lap around the sunflower, and strangers pause to admire the art. In April 2003, of 507 pedestrians observed to pass through the intersection, 164 (32%) interacted with the piazza in ways similar to those described above, compared with 7% ($P<.01$) at a similar, unimproved intersection. Walking and biking seems to have increased, as people go out of their way to enjoy the richness of the urban experience at the Sunnyside Piazza.

A perceived sense of community was documented as part of a cross-sectional survey that systematically sampled participants within a 2-block radius of the Sunnyside Piazza and participants of an adjacent neighborhood with a similar demographic profile (participation rate=60%). Of 97 Sunnyside Piazza residents interviewed, 65% (n=63) rated their neighborhood an excellent place to live, compared with 35% (52 of 147) at the control site ($P<.01$).

No statistically significant differences were found between the sites regarding whether residents believed that their neighborhood was a good place for children to grow up (43% vs 36% at the control site) or whether decisions that affected the neighborhood could be influenced by working together (47% vs 40%). However, a convenience sample of over 50 written comments collected on-site from passersby and participants during the painting of the intersection demonstrated the positive impact; one comment read, "It is primarily through the strength and joy of our community involvement that we begin to heal the alienation and disconnectedness, so prevalent in American cities." In the Sunnyside Piazza neighborhood, 86% of respondents reported excellent or very good general health, compared with 70% in the adjacent neighborhood ($P<.01$), and 57% versus 40% felt "hardly ever depressed" ($P<.01$).

A limitation of these findings is the potential of effect distortion through confounding. We are currently addressing this potential limitation through longitudinal measurements on an individual level.

NEXT STEPS

This "intersection repair" project, which has institutionalized the bureaucratic approval process through city ordinances, has gained support from urban planners, politicians, and citizens.

FIGURE 2—With the gigantic sunflower in the middle of the intersection drawing people into its center, the Sunnyside Piazza is how a focal point for community events.

Thus, it is now possible to implement additional sites throughout the city and work with communities to meet their needs. Furthermore, we are now in a position to design a panel study with pre- and postintervention measurements on the same study subjects, thereby controlling for potential confounding. Intersection repair projects will be realized in 3 communities in the coming months. We are in the process of administering such a survey to measure sense of community, social interactions, perceived neighborhood control and participation, and self-reported indicators of physical and mental health. If improvements in social networks, community capacity, and well-being can be documented, it can be argued that neighborhood organizing around urban design can improve the health of the public. ■

FIGURE 3—Cob art wall, made from clay, straw, sand, and water, and cob kiosk with bulletin board. Mosaics on the wall and in the fountain mimic the sunflower design.

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This project would not have mastered the bureaucratic and logistical hurdles without the dedicated commitment and hard work of Daniel Lerch and Mark Lakeman from The City Repair Project. Lisa Weasel, Renee Pype, Alexia Zerbinis, Keyan Mizani, Brian Borello, Mina Hensen, Charlie Hales, and Robert Burchfield were instrumental to the implementation of the Sunnyside Piazza. Tanya March and Portland State University Capstone students collected survey data in the field. Sukita Crimmel and Rob Bauman created the art wall and information kiosk with the help of the hundreds of hard-working hands and feet of schoolchildren and community members.

References

1. Kumanyika SK. Minisymposium on obesity: overview and some strategic considerations. *Annu Rev Public Health.* 2001;22:293–308.

2. Hu FB, Manson JE, Stampfer MJ, et al. Diet, lifestyle, and the risk of type 2 diabetes mellitus in women. *N Engl J Med.* 2001;345:790–797.

3. Narrow WE, Rae DS, Robins LN, Regier DA. Revised prevalence estimates of mental disorders in the United States: using a clinical significance criterion to reconcile 2 surveys' estimates. *Arch Gen Psychiatry.* 2002;59:115–123.

4. Balfour JL, Kaplan GA. Neighborhood environment and loss of physical function in older adults: evidence from the Alameda County Study. *Am J Epidemiol.* 2002;155:507–515.

5. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002;23(suppl 2):64–73.

6. Weich S, Blanchard M, Prince M, Burton E, Erens B, Sproston K. Mental health and the built environment: cross-sectional survey of individual and contextual risk factors for depression. *Br J Psychiatry.* 2002;180:428–433.

7. Silver E, Mulvy EP, Swanson JW. Neighborhood and structural characteristics and mental disorders: Fairs and Dunham revisited. *Soc Sci Med.* 2002; 55:1457–1470.

8. Steptoe A, Feldman PJ. Neighborhood problems as sources of chronic stress: development of a measure of neighborhood problems, and associations with socioeconomic status and health. *Ann Behav Med.* 2001;23: 177–185.

9. Weaver N, Williams JL, Weightman AL, et al. Taking STOX: developing a cross disciplinary methodology for systematic reviews of research on the built environment and the health of the public. *J Epidemiol Community Health.* 2002;56:48–55.

10. Wilson WJ. When work disappears: the world of the new urban poor. New York, NY: Vintage Press; 1996.

11. City Repair Project. Available at: http://www.cityrepair.org. Accessed April 17, 2003.

KEY FINDINGS

- Engaging city officials and community members early in the planning stages accommodated their ideas and concerns and facilitated completion of the Sunnyside Piazza project.
- Collaboration between urban planners, community groups, and nonprofit organizations helped to implement new urban design features that are conducive to social interactions and community stewardship.
- Creating an artistic public gathering place fostered social capital and social cohesion that may reverse alienation and isolation.

Zoning Out Crime and Improving Community Health in Sarasota, Florida: "Crime Prevention Through Environmental Design"

| Sherry Plaster Carter, MURP, AICP, Stanley L. Carter, Police Captain (Ret.), and Andrew L. Dannenberg, MD, MPH

Sarasota, Fla, used Crime Prevention Through Environmental Design (CPTED) principles to guide revitalization efforts in its crime-ridden North Trail area. A team of city planners, police officers, and architects examined land use and crime data and sought input from local businesses, residents, and community leaders.

Beginning in 1990, interventions included increased police patrols to reduce prostitution and the creation of a new zoning district to encourage area redevelopment based on CPTED principles. Compared with the rest of Sarasota, from 1990 to 1998 the North Trail Corridor experienced decreases in calls for police service ($P<.005$), crimes against persons and property ($P=$not significant), and prostitution ($P<.05$).

These results suggest that community design may be a useful tool for decreasing crime and improving community health.

CRIME IN THE UNITED STATES has significant impacts on the health of the public. While most responsibility for addressing crime has been given to the police and the criminal justice system, the public health community has become interested in crime prevention as a means of preventing the physical injuries and mental distress experienced by crime victims.[1] Reducing crime through better design of the physical environment is an approach that holds promise.[2] Known as Crime Prevention Through Environmental Design (CPTED), its key principles include facilitating the visibility of people's activities ("eyes on the street"), natural access control to manage ingress and egress, territorial reinforcement to distinguish public and private spaces, and ongoing maintenance to sustain the other principles.[3–6]

In 1990, the City of Sarasota, Fla, sought to incorporate CPTED strategies to revitalize its North Trail area, where aging buildings, restrictive zoning codes, and the presence of prostitutes along the major thoroughfare (US 41) discouraged economic investment and lowered the quality of life. The focus of the study was US 41, referred to as the North Trail Corridor.

TEAMWORK

Leadership came from a city administrative CPTED task team of planners and law enforcement officers who collaborated closely with architects, landscape architects, educational leaders, business owners, and local residents. Workshops held for community input and surveys of local businesses and residents revealed concerns about crime, particularly prostitution and drugs, as well as about poor property maintenance, land use, and zoning code enforcement. A review of crime data revealed that most prostitution violations occurred in the North Trail area, where there is an abundance of small "mom & pop" motels. Examination of land use data found that many North Trail motels and businesses were unable to renovate because of zoning barriers. Restrictive street setback requirements and parking and drainage requirements prevented or greatly increased the costs of renovating old businesses or building new ones.

POLICE INITIATIVES

In 1990, the city police department began high-visibility patrols to discourage prostitutes and their customers, undercover work to arrest prostitutes and drug dealers, and collaboration with hotel and motel owners to identify and arrest pimps and drug dealers. From 1990 through 1993, these efforts helped build public confidence in the city's ability to revitalize the area, which raised expectations for improvement and decreased citizens' tolerance of criminal behavior. Routine law enforcement efforts continued in subsequent years.

LONG-TERM PLANNING ACTION

In 1992, the city planners, working closely with community leaders, created a new zoning district (NT District) to "promote development and redevelopment in a manner that creates a safe

and attractive environment."[7(p3)] The ordinance required that all new developments in the NT District be reviewed for concordance with CPTED principles and that comments from such reviews be considered recommendations rather than requirements (Table 1). Most property owners willingly complied.

The rules required that outside lighting be installed and maintained for building entrances, walkways, and parking lots, and that landscaping with ground cover and canopy trees be designed to allow visibility, demonstrate ownership, and enhance the pedestrian environment. The new district encouraged architects to design buildings with porches, balconies, and residential space above street-level retail space, and parking that could be shared by residential and business users. These CPTED requirements discourage illegal behavior and make the environment more comfortable for legitimate behavior. Additionally, the new district allowed for a wider variety of land uses. Within months, several motels changed to antique shops, furniture stores, or other commercial or educational uses.

RESULTS

For 1990 through 1998, police data were available for the North Trail Corridor and for the rest of the city of Sarasota (excluding the North Trail Corridor) to evaluate changes in 4 measures of crime: calls for police service, crimes against persons or property, narcotic crimes, and prostitution (Table 2). Crimes against persons or property include murder, rape, robbery, aggravated assault, burglary, larceny, motor vehicle theft, and arson. The trends in the North Trail Corridor and in the rest of the city for each of the 4 measures were assessed through linear regression; we compared the slopes of these trends by use of a *t* test.

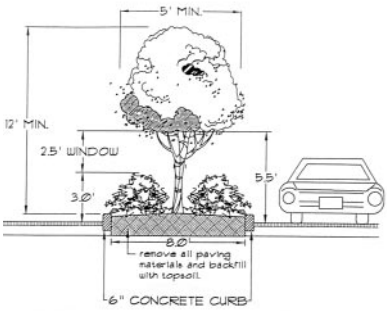
From 1990 through 1998, calls for service decreased in the North Trail Corridor and increased in the rest of the city; the slopes of the corresponding regression lines were significantly different ($P<.005$) (Table 2). The number of police reports of crimes against persons or property decreased in both the North Trail Corridor and the rest of the city; the slopes of these decreases were not significantly different. While the number of police reports of narcotics crimes increased in both the North Trail Corridor and the rest of the city, the slope of the increase in the North Trail Corridor was significantly less than that for the rest of the city ($P<.005$). Finally, the number of police reports of prostitution decreased in the North Trail Corridor and increased in the rest of the city; the slopes of these changes were significantly different ($P<.05$).

DISCUSSION

The observed improvements in several measures of crime suggest that community interventions in the North Trail area, including CPTED-related zoning changes and enhanced law enforcement activities, contributed to making the area safer over time. The planning process itself improved the social capital of the

KEY FINDINGS

- Planners and police officers, working closely with the community, can identify problems and initiate a combination of interventions that can bring about long-term reductions in criminal behavior.
- Focused police initiatives are a valuable first step in creating a safer environment.
- Crime Prevention Through Environmental Design principles incorporated into land use regulations provide a basis for developing and redeveloping a safe and attractive built environment over time, thereby having a long-term positive impact upon community health.
- Citizen involvement is critical to long-term success.
- Community crime prevention requires a comprehensive approach.



Left: **Before creation of the NT (North Trail) District: the Best Western Hotel was hidden from the road by landscaping, had a poorly defined entryway, and lacked sight lines from the interior to the exterior.**

Center: **After creation of the NT District: the front of the Best Western Hotel was expanded and windows were added to provide visibility for the sidewalk, driveway, and parking areas; at night, lights from the hotel combine with the public lighting to create a safe and attractive environment.**

Right: **The NT District's landscaping requirement of canopy trees and ground cover provides a 2.5-foot window of visibility 3 feet from the ground for pedestrians and drivers.**

PROFILE OF THE NORTH TRAIL AREA

- 18% of city area (2.2 square miles)
- 19% of permanent population (9807 persons)
- Sarasota/Bradenton Airport
- 3 colleges and performing arts center
- 38 hotels and motels (76% built in the 1940s and 1950s)
- Average of 34 000 vehicles daily on US 41
- 24% of citywide criminal incidents
- 81% of citywide prostitution incidents
- Gateway 2000 (active community organization)

Source. City of Sarasota Planning Department Files, "North Trail Sector Study," 1990.

TABLE 1—Crime Prevention Through Environmental Design (CPTED) Principles Used in the Effort to Revitalize the North Trail Corridor, Sarasota, Fla

Provision for natural surveillance

- The placement and design of physical features to maximize visibility. This will include building orientation, windows, entrances and exits, parking lots, walkways, guard gates, landscape trees and shrubs, fences or walls, signage, and any other physical obstructions.
- The placement of persons and activities to maximize surveillance possibilities.
- Lighting that provides for nighttime illumination of parking lots, walkways, entrances and exits.

Provision for natural access control

- The use of sidewalks, pavement, lighting, and landscaping to clearly guide the public to and from entrances and exits.
- The use of fences, walls, or landscaping to prevent and to discourage public access to or from dark and unmonitored areas.

Provision of territorial reinforcement

- The use of pavement treatments, landscaping, art, signage, screening, and fences to define and outline ownership of property.

Maintenance

- The use of low-maintenance landscaping and lighting treatment to facilitate the CPTED principles of natural surveillance, natural access control, and territorial reinforcement.

Source. City of Sarasota Ordinance 92-3562, Section 8-323, 1992. Available at: http://www.cpted.net/ordinance.html. Accessed August 7, 2003.

community by engaging local businesses, residents, and government in reviewing the issues and proposing solutions.[8–11] During the process, business owners started a merchants association and made physical improvements prior to code changes. Increases in the number of calls for police service in 1992 and 1993 indicate a higher level of citizen intolerance for crime. Together, the physical changes and raised social expectations created an environment less tolerant of criminal behavior.

Several limitations should be considered in interpreting the study results. While informal comments from local residents suggest substantial community improvements,[12] formal surveys to document changes in public perception were not conducted. Such surveys would be key for future studies. It is not possible to determine the impact of individual components of the interventions used, such as the increased police patrols. Other unmeasured

TABLE 2—Trends in Police Crime Data for the North Trail Corridor[a] and the Rest of the City of Sarasota, Fla, by year: 1990–1998

	1990	1991	1992	1993	1994	1995	1996	1997	1998
Calls for police service									
North Trail Corridor	8 843	8 653	9 804	9 525	8 865	9 414	8 853	7 701	6 777
Rest of city	63 758	64 527	65 354	64 570	66 629	69 615	73 377	75 447	68 310
Crimes against persons or property									
North Trail Corridor	1 395	1 379	1 638	1 378	996	1 054	827	750	730
Rest of city	7 833	8 140	8 096	7 586	7 088	7 448	7 599	7 467	6 449
Narcotic crimes									
North Trail Corridor	62	67	114	98	106	128	115	121	99
Rest of city	687	543	495	531	735	822	1 194	1 399	1 044
Prostitution									
North Trail Corridor	121	89	140	76	55	27	86	63	81
Rest of city	63	57	10	51	44	31	69	68	183

Note. Comparison of slopes of trend lines by linear regression and 2-tailed t test with 14 degrees of freedom is as follows: calls for police service: $t = -3.905$, $P < .005$; crimes against persons or property: $t = 0.722$ (not significant); narcotic crimes: $t = -3.454$, $P < .005$; prostitution: $t = -2.486$, $P < .05$.
Source. Sarasota Police Department Advanced Information Management Reports 30-02 and 30-04.
[a]Within the North Trail area, the North Trail Corridor is the primary commercial portion that lies along the North Tamiami Trail (US 41).

events such as private property improvements, social expectations, nearby downtown redevelopment efforts, or some combination of efforts and changes could have influenced the study results.

The experience in Sarasota highlights the impact of the built environment on crime and the importance of a comprehensive approach for designing, implementing, and evaluating interventions that may improve the health of a community. ■

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S.P. Carter conceived and managed the North Trail Sector study for the City of Sarasota, wrote the ordinance with the CPTED requirements, and provided the original manuscript, final edits, and photographs for the submittal. S.L. Carter provided leadership for the law enforcement effort for the project and compiled crime data for the statistical analysis. A.L. Dannenberg provided the public health perspective, completed the statistical analysis, and contributed substantially to revisions.

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References

1. Kawachi I, Kennedy BP, Wilkinson RG. Crime: social disorganization and relative deprivation. *Soc Sci Med.* 1999;48:719–731.

2. Jeffery CR. *Crime Prevention Through Environmental Design.* Rev ed. Beverly Hills, Calif: Sage Publications Inc; 1977.

3. Crowe TD. *Crime Prevention Through Environmental Design: Applications of Architectural Design and Space Management Concepts.* 2nd ed. Boston, Mass: Butterworth-Heinemann; 2000.

4. Jacobs J. *The Death and Life of Great American Cities.* New York, NY: Modern Library Edition; 1993.

5. Newman O. *Defensible Space: Crime Prevention Through Urban Design.* New York, NY: MacMillan; 1973.

6. City of Sarasota Resolution 91R-425, 1991. Available at: http://www.cpted.net/ordinance.html. Accessed April 22, 2003.

7. City of Sarasota Ordinance 92–3562, 1992. Available at: http://www.cpted.net/ordinance.html. Accessed April 22, 2003.

8. Zahm D. *Designing Safer Communities: A Crime Prevention Through Environmental Design Handbook.* Washington, DC: National Crime Prevention Council; 1997.

9. Zelinka A, Brennan D. *SafeScape: Creating Safer, More Livable Communities Through Planning and Design.* Washington, DC: Planners Press; 2001.

10. Plaster Carter SP, Carter SL. *Planning for Prevention.* Tallahassee, Fla: Florida Criminal Justice Institute; 1993.

11. Carter SP. Community safety: beyond the basics. *Public Management.* June 2002:16–18.

12. Hull V. Paving a new trail: designs for crime prevention. *Sarasota Herald Tribune.* October 7, 1996:A1.

Creating Healthy Communities, Healthy Homes, Healthy People: Initiating a Research Agenda on the Built Environment and Public Health

Mounting evidence suggests physical and mental health problems relate to the built environment, including human-modified places such as homes, schools, workplaces, parks, industrial areas, farms, roads and highways. The public health relevance of the built environment requires examination.

Preliminary research demonstrates the health benefits of sustainable communities. However, the impact of mediating and moderating factors within the built environment on health must be explored further. Given the complexity of the built environment, understanding its influence on human health requires a community-based, multilevel, interdisciplinary research approach.

The authors offer recommendations, based upon a recent conference sponsored by the National Institute of Environmental Health Sciences (NIEHS), for research and policy approaches, and suggest interagency research alliances for greater public health impact. (*Am J Public Health.* 2003;93:1446–1450)

Shobha Srinivasan, PhD, Liam R. O'Fallon, MA, and Allen Dearry, PhD

THE BUILT ENVIRONMENT— human-modified places such as homes, schools, workplaces, parks, industrial areas, farms, roads and highways—is our most important habitat, since 80% of North Americans live in towns and cities and spend 90% of their time indoors.[1] To date, much discussion of the built environment has focused on the challenges of providing adequate transportation (roads, highways, infrastructure, public transportation), urban sprawl, air pollution due to increased traffic, the lack of sidewalks, and the diminishing natural environment. New evidence, however, increasingly recognizes that even the places we live and work clearly affect our health.[2] Nevertheless, causal relationships between the built environment and specific human illnesses are often difficult to ascertain.[3]

Recent research explores the effect of improved built environments on physical activity,[4] asthma,[5] obesity,[6] cardiovascular disease, lung cancer mortality,[7] and mental health.[8,9] However, a pressing need remains for more concerted research to identify mechanisms by which the built environment adversely and positively impacts health and to develop appropriate interventions to reduce or eliminate harmful health effects. The growing health burden and attendant economic costs associated with higher chronic disease incidence (e.g., obesity, asthma, cardiovascular disease, cancer) require such research efforts. These complex diseases are attributable to an interaction of genetic and environmental influences, and many of the latter can be directly connected to the built environment. While research has focused on the negative public health consequences of the built environment, there has been very limited focus on the benefits of living in sustainable communities. A research agenda on the public health and quality-of-life benefits of sustainable communities is necessary.

DEFINITIONS

Built Environment

Scientists' understanding of the "built environment" has undergone several changes. Health Canada's[10] definition of the built environment has been modified as follows and provides a framework for this discussion:

> The built environment includes our homes, schools, workplaces, parks/recreation areas, business areas and roads. It extends overhead in the form of electric transmission lines, underground in the form of waste disposal sites and subway trains, and across the country in the form of highways. The built environment encompasses all buildings, spaces and products that are created or modified by people. It impacts indoor and outdoor physical environments (e.g., climatic conditions and indoor/outdoor air quality), as well as social environments (e.g., civic participation, community capacity and investment) and subsequently our health and quality of life.

Environmental Health

The scientific community's definition of "environmental health" also has changed in recent years. Two decades ago, the study of environmental health focused almost exclusively on chemical toxicants and their relationship to cancer and other illnesses. Now the definition of environmental health is much broader, and researchers are studying the effects on human health of the physical and social environment, which includes issues related to urban and rural development, appropriate uses of land, pesticide use, public transportation systems, and industrial development.[11] This change is reflected in the U.S. Department of Health and Human Service's (DHHS) *Healthy People 2010*[12] current definition of environmental health:

> In its broadest sense, environmental health comprises those aspects of human health, disease, and injury that are determined or influenced by factors in the environment. This includes not only the study of the direct pathological effects of various chemical, physical, and biological agents, but also the effects on health of the broad physical and social environment, which includes housing, urban development, land-use and transportation, industry, and agriculture.

Thus, the broader definition of "environmental health" encompasses the "built environment" within its scope and provides the context for future research.

THE BUILT ENVIRONMENT AND HEALTH

Research on the connections between the built environment and health has largely focused on housing, transportation, and neighborhood characteristics. These research endeavors have also pointed out that the burden of illness in the built environment has been greater on lower socioeconomic strata and minority populations. This section reviews some of the literature in these areas.

Housing

The association between substandard housing and health has long been recognized.[13,14] However, only recently has a growing body of evidence emerged suggesting that physical and mental health problems—anxiety, depression, attention deficit disorder, substance abuse, aggressive behavior, asthma, heart disease, and obesity—relate to the built environment, particularly to poor urban planning and inadequate housing.[15,16] Inadequate housing, for example, may indicate that inhabitants are under significant physical and mental stress.[13, 17] Dilapidated housing—leaking pipes, peeling paint, or cracks and holes in ceilings—may be a stressor that affects the human immune system.[5,18]

Housing disrepair among the poor exposes them disproportionately to lead, pests, air pollutants, contaminants, and greater social risks.[5,13] Pest sightings increase when buildings are dilapidated, and no amount of cleaning can remove the pest problem when such structural disrepair remains uncorrected. Further, pesticide use in dilapidated structures may jeopardize the health of inhabitants.[19,20]

Transportation

In recent decades, US residents have had a greater reliance on cars and trucks, which burn fossil fuels, for transportation needs. Increased vehicle use and the methods employed in energy generation contribute to air pollution that negatively impacts health.[21] In sprawling communities, cars and trucks pollute the atmosphere with ground-level ozone and particulate matter, contributing to human health problems such as lung disease.[22,27] People most affected by air pollution include older adults with preexisting respiratory disease,[23] children, especially those with asthma,[24] persons with inadequate health care, and even healthy individuals who work and exercise outdoors.[24,25]

Higher dependence on motor vehicles also has resulted in higher levels of congestion[26] and increased motor and pedestrian injuries and deaths.[27] Lack of safe sidewalks in growing urban areas has resulted in a reduction in the number of children walking or biking to schools.[12] Today, only 10% of children walk or bicycle to school—a 40% reduction over the last 20 years.[28] Research indicates that inadequate urban planning, including a dearth of bike paths and sidewalks, has contributed to an increasingly sedentary lifestyle for children, possibly factoring into the growing rates of childhood obesity.[29]

Isolated Communities and Sedentary Lifestyles

Mounting evidence suggests that there are social, health, and economic consequences to isolated and sedentary lifestyles.[30] Unfortunately, the physical and social construct of the urban environment promotes isolation.[17] Higher rates of television viewing, increased computer usage, concern about crime, little contact with neighbors and geographic isolation have created communities that are not interconnected.[29] This isolation may result in a lack of social networks and diminished social capital,[31] which can contribute to obesity, cardiovascular disease, mental health problems, and increased rates of mortality.[17,32–34] People who live in such isolated communities are often unable to effect changes or deal with crises or public health challenges. Studies suggest that a reduction in childhood and adolescent obesity, for example, through various intervention and prevention programs, would yield long-term economic benefits.[29,30]

Health Disparities

In exploring the impact of the built environment on public health, research indicates that the burden of illness is greater among minorities and low-income communities.[17,29,32–33] Lower–socioeconomic status communities usually have limited access to quality housing stock and live in neighborhoods that do not facilitate outdoor activities or provide many healthy food options.[35] Inequities in construction and maintenance of low-income housing, especially for Blacks, older persons, persons with disabilities, and immigrants, have resulted in insufficient housing, poor quality housing, overcrowding, and higher levels of population density and health problems.[16,36] Consequently, these communities may experience greater rates of respiratory disease, developmental disorders, obesity, chronic illnesses, and mental illness.

Also, studies have consistently shown an association between a deteriorated physical environment and higher rates of crime, making neighborhoods less safe for walking and in some cases resulting in greater social isolation.[37,38] Understanding linkages between socioeconomic inequity and health is essential to reducing exposures to environmental hazards as well as disparities in health.

SUSTAINABLE COMMUNITIES

While some research indicates the negative health impact of the built environment, there is very limited research on the health benefits of promoting sustainable communities. The President's Council in 1993 offered a working definition for sustainable communities as "healthy communities where natural and historic resources are preserved, jobs are available, sprawl is contained, neighborhoods are secure, education is lifelong, transportation and health care are accessible, and all citizens have opportunities to improve the quality of their lives."[39] The sparse research on sustainable communities suggests that diligent planning is needed to create an environment that is conducive to the mental and physical well-being of humans as well as the natural environment.[40,41] These studies contend that health benefits exist when people come into contact with the natural environment. The studies recommend both the creation of green spaces and the use of environmentally conscious construction.[42]

Some argue that urban sprawl has created more highways, thus causing greater air pollution. With the expansion of urban areas and the resultant sprawl, agriculture has become more dependent on the use of pesticides and mechanisms that can produce larger quantities of food in

smaller areas. All this has had a debilitating impact on human health, resulting in greater rates of asthma and other respiratory problems.

Accordingly, there have been recommendations to develop green infrastructures to address the ecological and social impacts of sprawl and their impact on health.[43] Examples of the principles behind incorporating green spaces and environmentally conscious construction in the built environment include using natural daylight, solar collectors, passive cooling, and nontoxic materials; harvesting rainwater; installing operable (openable) windows; creating pedestrian and bike greenways; and filling building structures with plants, water, art, light, and natural air. Studies indicate health and occupational benefits from using some or all of these design principles through lowering workplace stress and employee absenteeism, enhancing and preserving land, reducing energy waste, and reducing expenditures by having lower energy and maintenance costs.[44] These studies have argued that these kinds of sustainable communities may in the long run translate into a healthier economy.

ADDRESSING THE CHALLENGES

Current research on the relationship between urban design and human illness is inconclusive and requires further exploration. There is limited research on measures and methods to quantify the health benefits of improved urban planning, including an examination of land-use policies that could support sustainable and nonpolluting agricultural and industrial systems.[45] To address some of these gaps, the National Institute of Environmental Health Sciences (NIEHS) convened a conference called the "Built Environment—Healthy Communities, Healthy Homes, Healthy People: Multilevel, Interdisciplinary Research Approaches," in July 2002 in Research Triangle Park, North Carolina. The National Institutes of Health's Office of Rare Diseases and Office of Behavioral and Social Science Research cosponsored the conference.

As its objective, the conference sought to delineate areas of research to better understand the connection between specific illnesses and health challenges in the built environment. A broad spectrum of participants representing community organizations, state and local departments of health, academic researchers, and federal agencies participated. They discussed the state of the science and explored future directions in conducting research on the built environment and health. Speakers described current research and examined connections between the built environment and human health and discussed challenges in developing sustainable communities that seek to balance the social, economic, cultural, and ecological infrastructure with human health and development.

The conference participants derived their major recommendations from current literature; they found gaps in the literature and research on sustainable communities, and they found that it focuses predominantly on the adverse health effects of the built environment, with very little focus on the positive health impacts of sustainable communities. To encourage research in this area, major recommendations from the meeting included the following:

- Develop effective measures and indicators for sustainable communities.
- Conduct multidisciplinary research on the positive health impacts of sustainable and planned communities.
- Assess the environmental health benefits of efficient or alternate energy (for transportation, agriculture, architecture, community design, and so on).
- Develop models to incorporate cost-effectiveness when adopting environmentally sustainable technologies.
- Create coordinated programs among federal and nonfederal agencies that address research on the built environment.
- Encourage multidisciplinary programs for training and research within governmental and nongovernmental agencies.
- Improve communication and partnership strategies among various entities; especially encourage community participation in research endeavors.
- Develop multilevel techniques of measurement and longitudinal models of analysis for assessing the impact of the built environment on sustainable communities. These measures and models should account for individual, community, and systemic variables including biological factors, socioeconomic factors, and neighborhood and physical environment variables.
- Identify factors and variables that mediate and moderate built environment health effects.
- Study methods and channels to translate research findings into policy and to the community-at-large that improve public health.

STRATEGIES FOR IMPLEMENTATION

The built environment poses many complex challenges that involve physical and social environments. In spite of research indicating that chronic diseases of the 20th century, such as heart disease, obesity, asthma, and others, are affected by how we design, build, and sustain our environment, many communities and planners still do not fully understand the health consequences of environmental factors. This stems partly from the sparse research concerning the health benefits of sustainable communities. Creating communities that are conscious of environmental health concerns may require partnerships and collaborations among policymakers, governments, researchers, communities, and health specialists with interdisciplinary perspectives.

Awareness of environmental health consequences requires not only collaborative partnerships but also the adoption of multidisciplinary research approaches to environmental health, such as studies that include public health researchers, health professionals, architects, builders, planners, and transportation officials. Such multidisciplinary coalitions would be better equipped to develop indicators and measures of sustainable communities and to elucidate their association with environmental health.[39,46] These coalitions may be better equipped to: (1) determine what constitutes safe neighborhoods, (2) determine what constitutes safe and affordable housing, (3) provide green space for people to enjoy where they live and work, and (4) re-

think the modes of transportation and travel from one place to another.

Since 1993, the NIEHS has supported a series of translational research programs designed to establish sustainable mechanisms for educating the public about environmental health issues and for supporting individual and community involvement in the identification and investigation of environmental health concerns. The NIEHS developed the translational research programs to foster partnerships and alliances among various relevant parties keen on understanding the effects and risks to human health from exposure to physical and social environmental agents.

The NIEHS has defined translational research as the conversion of findings from basic, clinical, or epidemiological environmental health science research into information, resources, or tools that can be applied by health care providers and community residents to improve public health outcomes in at-risk neighborhoods. In addition, the NIEHS has given special attention to ensuring that the information is culturally relevant and understandable.[47]

In various programs under the auspices of translational research, such as the "Community-Based Participatory Research, Health Disparities, and Environmental Justice program," some research endeavors address aspects of the built environment. These research projects involve various combinations of partnerships among environmental health researchers, social scientists, health care providers, public health departments, and communities. They are multidisciplinary in their scope.

An example is the "Southern California Environmental Health Project,"[48] a collaborative effort between Communities for a Better Environment and the University of Southern California Environmental Health Center.[49] Their partnership successfully provided evidence to Los Angeles city planners concerning adverse health effects of air pollution on children in low-income, largely minority areas where oil refineries were located. In so doing, the partnership helped keep the oil refineries from reopening.

The Northern Manhattan Environmental Justice Partnership[49] in New York is another such project; it involves partnerships between the West Harlem Environmental Action and Columbia University. The partnerships have succeeded not only in conducting research in the community to assess the effects of diesel pollution but also in effecting policy change for rerouting buses and placing a time limit for idling of buses and trucks in neighborhoods.[49] These partnerships have allowed these projects to develop a more comprehensive and multidisciplinary research agenda and also initiate intervention and prevention programs to impact public health. Such multi-disciplinary endeavors could lead to a greater understanding of the costs of unhealthy indoor environments (not only schools and workplaces but also hospitals and in-vehicle environments), the health consequences of urban sprawl and associated housing, transportation and societal energy use.[50,51] ■

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References

1. Hancock T. Indicators of environmental health in the urban setting. *Can J Public Health.* 2002;93:45–51.

2. Wilson A, Seal JL, McManigal LA, Lovins LH, Cureton M, Browning WD. *Green Development: Integrating Ecology and Real Estate.* New York, NY: John Wiley; 1998.

3. Hodgson M. Indoor environmental exposures and symptoms. *Environ Health Perspect.* 2002;110:663–667.

4. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002;23:64–73.

5. Rauh VA, Chew GL, Garfinkel RS. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ Health Perspect.* 2002;110(suppl):323–327.

6. Morland K, Wing S, Diez Roux A, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med.* 2002;22:23–29.

7. Pope CA III, Burnett RT, Thun MJ, et al. Lung cancer, cardiopulmonary mortality, and long-term exposure to fine particulate air pollution. *JAMA.* 2002;287:1131–1141.

8. Halpern D. *More Than Bricks and Mortar? Mental Health and the Built Environment.* London, England: Taylor and Francis; 1995.

9. Weich S, Blanchard M, Prince M, Burton E, Erens B, Sproston K. Mental health and the built environment: cross-sectional survey of individual and contextual risk factors for depression. *Br J Psychiatry.* 2002;180:428–433.

10. Health Canada, Division of Childhood and Adolescence. *Natural and Built Environments.* Ottawa: Health Canada; 2002. Available at: http://www.hc-sc.gc.ca/dca-dea/publications/healthy_dev_partb_5_e.html. Accessed August 8, 2003.

11. Olden K. The complex interaction of poverty, pollution, and health status. *The Scientist,* February 16, 1998.

12. *Healthy People 2010: Understanding and Improving Health.* Washington, DC: US Dept of Health and Human Services; 2001. Also available at: http://health.gov/healthypeople/document. Accessed July 24, 2003.

13. Sharfstein J, Sandel M, Kahn R, Bauchner H. Is child health at risk while families wait for housing vouchers? *Am J Public Health.* 2001;91:1191–1192.

14. Thomson H, Petticrew M, Morrison D. Health effects of housing improvement: systematic review of intervention studies. *BMJ.* 2001;323:187–190.

15. Raffestin C, Lawrence R. An ecological perspective on housing, health and well-being. *J Sociol and Soc Welfare.* 1990;17:143–160.

16. Fullilove MT, Fullilove RE. What's housing got to do with it? *Am J Public Health.* 2000;90:183–184.

17. Bashir SA. Home is where the harm is: inadequate housing as a public health crisis. *Am J Public Health.* 2002;92:733–738.

18. Lehmann I, Thoelke A, Weiss M et al. T cell reactivity in neonates from an East and a West German city—results of the LISA study. *Allergy.* 2002;57:129–36.

19. Cummins SK, Jackson RJ. The built environment and children's health. *Pediatr Clin North Am.* 2001;48:1241–1252.

20. Kreiger J, Higgins DL. Housing and health: time and again for public health action. *Am J Public Health.* 2002;92:758–768.

21. Bell ML, Davis D, Cifuentes L et al. International expert workshop on the analysis of the economic and public health impacts of air pollution: workshop summary. *Environ Health Perspect.* 2002;110:1163–1168.

22. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002;117:201–217.

23. Spannhake EW, Reddy SP, Jacoby DB, Yu XY, Saatian B, Tian J. Synergism between rhinovirus infection and oxidant pollutant exposure enhances airway epithelial cell cytokine production. *Environ Health Perspect.* 2002;110: 665–670.

24. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet.* 2002;359:386–391.

25. Redd SC. Asthma in the United States: burden and current theories. *Environ Health Perspect.* 2002;110(suppl): 557–560.

26. Zein SR, Geddes E, Hemsing S, Johnson M. Safety benefits of traffic calming. *Transportation Res Rec.* 1997; 1578:3–10. Also available at: http://ite.org/traffic/documents/tcir0209.pdf. Accessed July 24, 2003.

27. Ewing R, Pendall R, Chen D. *Measuring sprawl and its impact.* Washington DC: Smart Growth America; 2002. Also available at: http://www.smartgrowthamerica.org/sprawlindex/sprawlindex.html. Accessed July 24, 2003.

28. Killingsworth RE, Lamming J. Development and public health. *Urban Land.* July 2001:12–17.

29. Goran, MI, Treuth MS. Energy expenditure, physical activity, and obesity in children. *Pediatr Clin North Am.* 2001;48:931–953.

30. Wang G, Dietz WH. Economic burden of obesity in youths aged 6 to 17 years: 1979–1999. *Pediatrics.* 2002; 109:81–85.

31. Hawe P, Shiell A. Social capital and health promotion: a review. *Soc Sci Med.* 2000;51:871–885.

32. Fullilove MT. Promoting social cohesion to improve health. *J Am Med Woman's Assoc.* 1998;53:72–76.

33. Kawachi I. Social capital and community effects on population and individual health. *Ann N Y Acad Sci.* 1999; 896:120–130.

34. Adler NE, Ostrove JM. Socioeconomic status and health: what we know and what we don't. *Ann N Y Acad Sci.* 1999;896:3–15.

35. King AC, Castro C, Wilcox S, Eyler AA, Sallis JF, Brownson RC. Personal and environmental factors associated with physical inactivity among different racial-ethnic groups of US middle-aged and older-aged women. *Health Psychol.* 2000;19:354–364.

36. Leaderer BP, Belanger K, Triche E, et al. Dust mite, cockroach, cat, and dog allergen concentrations in homes of asthmatic children in Northeastern United States: impact of socioeconomic factors and population density. *Environ Health Perspect.* 2002;110:419–425.

37. Taylor RB, Harrell, AV. *Physical Environment and Crime.* Washington, DC: National Institute of Justice; 1996.

38. Kuo Fe, Sullivan WC. Environment and crime in the inner city: does vegetation reduce crime? *Environ and Behav.* 2001;33:343–367.

39. Clinton WJ. Executive Order 12852. President's Council on Sustainable Development. 1993. Available at http://envirotext.eh.doe.gov/data/eos/clinton/19930629.html. Accessed July 31, 2003.

40. Labonte R. A holosphere of healthy and sustainable communities. *Aust J Public Health.* 1993:17:4–12.

41. Hancock T. Healthy communities must also be sustainable communities. *Public Health Rep.* 2002;115:151–156.

42. Pederson RM, Robertson A, de Zeeuw H. Food, health and the urban environment. *Rev Environ Health.* 2000; 15:231–247.

43. Benedict MA, McMahon ET. *Green Infrastructure: Smart Conservation for the 21st Century.* Sprawl Watch Clearinghouse Monograph Series. Washington, DC: Sprawl Watch Clearinghouse; 2000.

44. Hedge A. Where are we in understanding the effects of where we are? *Ergonomics.* 2000;43:1019–1029.

45. von Schirnding YE. Health-and-environment indicators in the context of sustainable development. *Can J Public Health.* 2002;93:9–15.

46. Cappon D. Criteria for healthy urban environments. *Can J Public Health.* 1991;82:249–258.

47. National Institute of Environmental Health Sciences, Division of Extramural Research and Training. Environmental Justice: Partnerships for Communication. Available at http://www.niehs.nih.gov/translat/envjust/envjust.htm. Accessed July 24, 2003.

48. Porras C. The Southern California Environmental Health Project. National Institute of Environmental Health Sciences, Division of Extramural Research and Training Web site; Environmental Justice—Project Descriptions page. Available at http://www.niehs.nih.gov/translat/envjust/ej-desc2.htm#porras. Accessed July 24, 2003.

49. Shepard P. The Northern Manhattan Environmental Justice Partnership: expanding the community driven research agenda. National Institute of Environmental Health Sciences, Division of Extramural Research and Training Web site; Environmental Justice—Project Descriptions page. Available at http://www.niehs.nih.gov/translat/envjust/ej-desc2.htm#shepard. Accessed July 24, 2003.

50. Kjellstrom T, Corvalan C. Framework for the development of environmental health indicators. *World Health Stat Q.* 1995;48:144–154.

51. Corvalan C, Kjellstrom T, Smith KR. Health, environment and sustainable development: identifying links and indicators to promote action. *Epidemiology.* 1999;10:656–660.

Healthy Places: Exploring the Evidence

"Sense of place" is a widely discussed concept in fields as diverse as geography, environmental psychology, and art, but it has little traction in the field of public health. The health impact of place includes physical, psychological, social, spiritual, and aesthetic outcomes.

In this article, the author introduces sense of place as a public health construct. While many recommendations for "good places" are available, few are based on empirical evidence, and thus they are incompatible with current public health practice. Evidence-based recommendations for healthy place making could have important public health implications.

Four aspects of the built environment, at different spatial scales—nature contact, buildings, public spaces, and urban form—are identified as offering promising opportunities for public health research, and potential research agendas for each are discussed. (*Am J Public Health.* 2003;93:1451–1456)

Howard Frumkin, MD, MPH, DrPH

SOME PLACES ARE ROMANTIC, and some places are depressing. There are places that are confusing, places that are peaceful, places that are frightening, and places that are safe. We like some places better than others. Place matters.

"Sense of place" is a widely used term, and one that remains difficult to define. The antecedent Latin term, *genius loci*, referred not to a place itself but to the guardian divinity of that place. In modern, more secular times, the term connotes the *atmosphere* of a place, the quality of its *environment.* This matters because "we recognize that certain localities have an attraction which gives us a certain indefinable sense of well-being and which we want to return to, time and again."[1(pp157–158)]

The features of a place affect us in many ways. We gain spatial orientation—our sense of where we are and how to get where we are going—from place cues.[2, 3] Places can evoke memories, arouse emotions, and excite passions.[4,5] Some places have spiritual resonance; every religion has sacred places, some natural such as the Himalayas for Buddhists and Hindus[6] and some built such as the great Catholic cathedrals. Legends are grounded in places.[7] Places affect our performance as we work and study. Some places—the social gathering spots that sociologist Ray Oldenburg[8,9] has called "great good places"—help us connect with other people. Some places, as every vacationer knows, seem to enhance well-being. Some places may even promote good health.

The qualities of a place—and its potential impact on health—represent more than its physical features. Place is also a social construct. As noted by sociologists Kevin Fitzpatrick and Mark LaGory[10] in their discussion of inner-city neighborhoods:

> While a place's character is a function of physical qualities, it is also a product of risks and opportunities, the nature of the social organization attached to the locale, its political, social, and economic relationships with other places, the psychosocial characteristics of the individuals occupying the space, and the local cultural milieu. We learn to act in specific ways in certain places; we don't genuflect in bars or drink beer and eat popcorn in churches. Hence, our actions in various places are conditioned by a number of factors, all of which may operate on the individual to affect not only their [*sic*] behavior, but also their [*sic*] health.[10(p17)]

People are heterogeneous and vary in their responses to place. Some like forests, others like deserts, others like manicured back yards, and others like bustling city streets. A person's "place in the world," including socioeconomic status, sense of efficacy and opportunity, and cultural heritage, affects the experience of place.[11] As with any medication, infectious exposure, or toxin, a full understanding of the effect of places on people requires an understanding of human variability.

There is every reason for those who care about public health to care about place. If places have such varied and far-reaching effects on people, we would expect some places to surpass others in promoting health and well-being. There is an analogy to medications, for which we consider both efficacy and safety. The field of environmental health has focused much attention on safety, defining the dangers of such places as cliff edges, hazardous waste sites, and lead smelters. But what about efficacy? How do we know what makes a good place?

THE EVIDENCE OF GOOD PLACES

There is no shortage of guidelines on how to recognize, design, and build a good place. Where do these guidelines originate? Sources range from personal opinion to empirical data.

First, some guidelines appear as *ex cathedra* pronouncements. Much of the literature in architecture, art, and design exemplifies this approach. Authors declare what is beautiful and what is not, what works well and what does not, and how places ought to be built. It often makes for lively reading, but the reader may wonder: Says who? By what authority? Does this arrangement actually *work*? Does it make people happier or healthier? How would success be measured?

Second, some guidelines emerge out of deductive inference. The practice of Feng Shui, which begins with general principles of place and deduces specific recommendations about how to design rooms, homes, and other buildings, is an example.[12] So is the current interest in

biophilia, the theory that humans have an "innately emotional affiliation . . . to other living organisms."[13,14] On the basis of this theory, some authors have asserted that humans should be around natural places. While there is a certain amount of empirical evidence for both lines of thought, many recommendations have flowed directly from the conviction that nature contact must be a good thing—an application of general principle to specific actions.

Third, some guidelines emerge from qualitative observational research. Jane Jacobs' careful scrutiny of Greenwich Village, New York, in the 1940s and 1950s—walking its streets, visiting its shops, and lingering in its cafes—as recorded in her *Death and Life of Great American Cities*,[15] and William Holly Whyte's detailed photography of the sidewalks, parks, playgrounds, and streets of New York a generation later, as described in *The Social Life of Small Urban Spaces*[16] and *City: Rediscovering the Center*,[17] are classic examples. In the manner of anthropologists, these observers noted patterns that seemed to function well, such as mixed land uses around parks, and offered them as prescriptions for urban design.

Fourth, empirical studies of stated preference, published for the most part in the environmental psychology literature, have yielded conclusions about what makes good places. Rachel and Stephen Kaplan of the University of Michigan, pioneers in this research, have reviewed much of their work and that of others in *The Experience of Nature*[18] and *With People in Mind*.[19] Respondents are shown photographs of different kinds of places and asked to choose which they prefer. People consistently favor such features as a balance of trees and pasture, clear borders, and alluring paths that curve out of sight. The general features of preferred places that emerge include spatial definition, coherence, legibility, and mystery (the promise of learning more through exploration).

Finally, empirical research has demonstrated associations between certain aspects of place and behavioral and health outcomes.[20] For example, Ulrich[21] took advantage of an inadvertent architectural experiment. On the surgical floors of a 200-bed suburban Pennsylvania hospital, some patient rooms faced a stand of deciduous trees, while others faced a brick wall. Postoperative patients were assigned essentially at random to one or the other kind of room. Ulrich reviewed the records of cholecystectomy patients over a 10-year interval. Patients with tree views had statistically significantly shorter hospitalizations (7.96 days vs 8.70 days), less need for pain medications, and fewer negative nurses' notes than patients with wall views. These results suggest that views of trees have a salutary effect and, together with other evidence, support the notion that trees are part of a "good place."

Recent empirical studies have documented small-area geographic variability in lead toxicity,[22] childhood asthma,[23] disability among the elderly,[24] and infectious diseases,[25,26] among other outcomes, suggesting a role for place-based risk factors. Such findings resonate with modern medical and public health science and offer the prospect of evidence-based guidelines for healthy places.

A PLACE FOR PLACE IN PUBLIC HEALTH

The appreciation that place matters for health is not new. Twenty-five centuries ago, in *Airs, Waters, and Places*, Hippocrates helped his readers distinguish unhealthy places (such as swamps) from healthy places (such as sunny, breezy hillsides). Fredric Law Olmsted, the preeminent landscape architect and planner of the 19th century, explicitly placed human health at the heart of his work.[27,28] A half century ago, the American Public Health Association issued a set of standards, *Planning the Neighborhood*,[29] that addressed "the physical setting in which homes should be located." These standards addressed site selection, sanitary infrastructure, planting and landscape design, street layout, lighting, residential density, and community amenities. More recently, urban planners have recognized the implications of their work for public health,[30–33] and the field of medical geography has been reinvigorated,[34] including a new journal, *Health & Place*.

But today's challenges are different from those of the past. First, the built environment is far more complex, with more materials used in construction, more elaborate building systems, and more intricate urban networks. In some ways, technical advances have reduced health risks (indoor air is now far cleaner than in the days of wood- and coal-burning stoves), but new risks need to be better defined. Second, in a highly mobile society, traditional links to place may be weakened. If a "sense of place" has benefits for health and well-being, then understanding how to design for it may have real public health value. Third, many more aspects of design, construction, and transportation are regulated than in the past, if not by law then by voluntary standards. This requires that the evidence of how places affect health and well-being be collected and codified as well. Finally, in an age of electronic communication, such information is widely and instantaneously accessible. If it is useful in advancing public health, it can be useful on a large scale.

Members of the public increasingly value their health; consider the environment to be an important influence on health; and want to live, work, and play in healthy environments. Both professionals and members of the public increasingly expect health recommendations to be supported by solid data. For all of these reasons, then, public health needs to refocus on the health implications of place. We need a broad, vigorous research agenda, and we need to apply research findings to practice.

RESEARCH ON PLACE AND HEALTH

If health research needs to focus more on place, and if empirical research can profitably be applied to questions of place and health, what are the topics to be investigated? Four aspects of the built environment offer promising opportunities for health research: nature contact, buildings, public spaces, and urban form.

Nature Contact

Contact with nature seems to be good for health, at least for some people in some circumstances.[35] As noted earlier, there is evidence that nature views speed recovery among postoperative patients. In other studies,

contact with nature has been associated with fewer sick call visits among prisoners,[36] improved attention among children with attention deficit disorder,[37] improved self-discipline among inner-city girls,[38] decreased mortality among senior citizens,[39] lower blood pressure and less anxiety among dental patients,[40] and better pain control among bronchoscopy patients.[41] There is evidence that nature contact enhances emotional, cognitive, and values-related development in children, especially during middle childhood and early adolescence.[42] Nature contact has been credited with reducing stress and enhancing work performance.[18]

These findings have important potential implications for the design of the built environment. Should gardens be incorporated into housing? Should windows in offices offer views of trees? Should neighborhood parks include certain kinds of plantings? Should hospitals offer healing gardens to patients and their families? However, before such questions can be answered, research needs to be carried out. This research needs to include careful operational definitions of nature contact, including the kinds of nature (flowers? trees? animals?) and the kinds of contact (viewing? touching? entering?). It needs to include careful operational definitions of health endpoints. It needs careful specification of the populations that are studied, and of personal attributes of study participants, to help clarify individual and group variations in responses to nature contact. It also needs careful control of potential confounders and careful consideration of alternative hypotheses. For example, wilderness experiences may be salutary because of the benefits of companionship, being physically active, taking a vacation, or meeting a challenge, and not because of nature contact per se. As evidence emerges, we will have a clear basis for guidelines on incorporating nature contact into the built environment.

Buildings

Building design is a second arena in which health research offers great promise. Recent attention to "sick buildings" has focused attention on indoor air quality as a determinant of health.[43,44] Indeed, choosing building materials, furnishings, and cleaning agents that minimize indoor emissions; designing and operating effective ventilation systems; and maintaining air circulation and humidity at optimal levels are all recognized as important design strategies to protect health, and evidence-based recommendations are available.[45–48]

However, broader public health considerations apply as well. First, the design principles known as "green building" (see the US Green Building Council at http://www.usgbc.org, the Energy and Environmental Building Association at http://www.eeba.org, or EarthCraft Homes at http://www.southface.org/home/ech/earthcraft_home.htm),[49,50] geared primarily toward environmental sustainability, may offer substantial (if indirect) public health benefits. For example, designing for energy conservation may reduce the demand for energy, in turn reducing the emission of air pollutants from power plants. Similarly, using sustainably harvested wood may help reduce deforestation, slowing global climate change and preserving biodiversity. Public health research that takes full account of the health benefits of such environmental building practices will yield important insights.

Second, some aspects of building design are not generally recognized as having direct health impacts but deserve renewed attention. For example, despite the established health benefits of physical activity,[51] most modern buildings with more than 2 or 3 floors have conspicuous elevators in their lobbies, and staircases that are concealed and unappealing. Could the return of prominent, graceful, well-lit staircases seduce people into walking instead of riding to higher floors?

Similarly, although there is some evidence of the role of natural lighting in promoting comfort and performance,[52] not enough is known about how lighting can be designed to promote health. With the advent of energy-efficient compact fluorescent bulbs, this question takes on added importance. Finally, although substandard housing is clearly bad for health,[53] a recent review indicated that evidence of the health benefits of specific housing interventions is scarce.[54] How to design and build good homes, schools, and workplaces remains a pressing, and largely unanswered, health question.

Public Places

Many of the best places are neither home nor work, but "third places" in the public realm: streets and sidewalks, parks and cafes, theaters and sports facilities.[9] Such public places are important venues for a wide variety of activities, of which some—such as social interaction and physical activity—have clear health implications.[55,56]

What makes a good street? There is no shortage of design guidelines issued by government agencies and private groups. Those issued by state departments of transportation typically aim to maximize motor vehicle traffic flow and prevent collisions. Guidelines from other sources are oriented more toward pedestrians. Some, such as Dan Burden's *Street Design Guidelines for Healthy Neighborhoods*,[57] explicitly focus on health. Such sources typically recommend streets that are narrower and incorporate traffic-calming strategies; sidewalks with sufficient width, buffers, continuity, and connectivity; safe crosswalks; and bicycle lanes.

What about parks? Parks exist in a variety of settings, from urban pocket parks to waterfronts, from large expanses such as Cullen Park in Houston, Fairmont Park in Philadelphia, and Griffith Park in Los Angeles to reclaimed transportation corridors such as the C&O Canal between Washington, DC and Cumberland, Md.[58,59] Research on park use suggests that several design features play a role, including amount and type of vegetation; presence of interesting, meandering pathways; quiet areas for sitting and reading; recreational amenities; adequate information and signage; and perceived level of safety.[60] People's conceptions of parks, the expectations they bring to them, and the ways they use them vary greatly according to age, gender, ethnicity, and other factors.[61–63]

What features of street and park design predict social interactions and physical activity? A large literature provides some answers with regard to physical activity.[64–68] Proximity, accessibility, attractive scenery, good lighting, toilets and drinking water, and well-designed and well-maintained paths all seem

to predict physical activity. Less information is available regarding social interactions, but studies have suggested that "sense of community" increases when neighborhoods are walkable[69–71] and when well-maintained public spaces are located near homes.[72]

Again, much remains to be learned. If a sidewalk or trail is built, will people walk and bike? If a park is built, will people come? Which park designs are most restorative? What are the best ways to site, design, and build public places in ways that attract people, lift their spirits, encourage them to socialize, and promote physical activity?

Urban Form

Urban form results from design, transportation, and land use decisions at a larger scale than buildings and public places. In recent decades, the growing dominance of the automobile, the migration from central cities to suburbs, and zoning codes that segregate different land uses have resulted in the phenomenon known as "urban sprawl." There is no single pattern of urban sprawl, but principal features include low residential and employment density; separation of distinct land uses such as housing, employment, and retail sales; low connectivity among destinations; weak and dispersed activity centers and downtowns; and heavy reliance on automobiles with few available transportation alternatives.[73,74]

A corollary of suburban growth has been the decline of central cities. As jobs and economic activity migrated from the center to the periphery, the neighborhoods left behind became different kinds of places, with neglected and abandoned buildings, dilapidated and dangerous parks and streets, dysfunctional transportation systems, and failing infrastructures.[10,75] Poor people and members of minority groups are concentrated in such environments, raising profound social justice concerns.

Research has suggested that the land use and transportation patterns that characterize urban sprawl have health implications.[76] Heavy use of motor vehicles contributes to air pollution, which increases respiratory and cardiovascular disease as well as overall mortality. Declining physical activity, related to decreased walking, contributes to obesity, diabetes, and associated ailments. Increased time spent in traffic raises the risk of traffic crashes, and roads built for cars but not pedestrians pose a risk of pedestrian injuries and fatalities.

Mental health is threatened by factors as diverse as road rage and physical inactivity, and social capital—an important predictor of health, both directly and mediated through income inequality—may decline. At the same time, the complex of physical and social risk factors in the central city—the concentration of poverty, the dearth of social and medical services, the prevalence of substandard housing, the threats of crime and drug use, the squalor of many areas—are so well recognized that they have spawned a subfield, "urban health," with its own research centers, journals, and specialists.[77–81]

Urban form has much to do with health. Attention to the health problems of the center city has focused largely on social and organizational factors rather than features of the built environment. Similarly, health research on the consequences of suburban sprawl has been limited. Research is needed on a variety of issues. What urban arrangements, what zoning codes, what transportation plans, and what industrial policies lead to the most livable and healthy cities and suburbs? Of the many sweeping plans for urban design and urban renewal, that have come and gone over the years, which do the most for human health and welfare? What methods are available for "health impact assessment,"[82–86] and how are they best applied?

CONCLUSIONS

Public health needs to rediscover the importance of place. From nature contact to buildings, from public places to cities, there are research needs and unmet opportunities to design and build healthy places. As health professionals, urban planners and architects, transportation engineers and real estate developers, environmental psychologists and geographers learn the vocabularies and perspectives of each other's fields and pursue active collaborations, these research questions will be asked and answered with solid evidence, and healthier, more sustainable human environments will be envisioned, planned, and built. ■

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References

1. Jackson JB. *A Sense of Place, a Sense of Time.* New Haven, Conn: Yale University Press; 1994.
2. Tuan Y-F. *Space and Place: The Perspective of Experience.* Minneapolis, Minn: University of Minnesota Press; 1977.
3. Kaplan S, Kaplan R, eds. *Humanscape: Environments for People.* Ann Arbor, Mich: Ulrich's Books; 1982.
4. Walter EV. *Placeways: A Theory of the Human Environment.* Chapel Hill, NC: University of North Carolina Press; 1988.
5. Lippard LR. *The Lure of the Local: Senses of Place in a Multicentered Society.* New York, NY: New Press; 1997.
6. Bernbaum E. The Himalayas, realm of the sacred. In: Swan JA, ed. *The Power of Place: Sacred Ground in Natural and Human Environments.* Wheaton, Ill: Quest Books; 1991: 107–119.
7. Abram D. *The Spell of the Sensuous.* New York, NY: Pantheon Books: 1996.
8. Oldenburg R. *The Great Good Place: Cafés, Coffee Shops, Community Centers, Beauty Parlors, General Stores, Bars, Hangouts and How They Get You Through the Day.* New York, NY: Paragon House; 1989.
9. Oldenburg R. *Celebrating the Third Place: Inspiring Stories About the "Great Good Places" at the Heart of Our Communities.* New York, NY: Marlowe & Co; 2000.
10. Fitzpatrick K, LaGory M. *Unhealthy Places: The Ecology of Risk in the Urban Landscape.* New York, NY: Routledge; 2000.
11. Eyles J. *Senses of Place.* Warrington, England: Silverbrook Press; 1985.
12. Hale G. *The Practical Encyclopedia of Feng Shui.* London, England: Hermes House; 1999.
13. Wilson EO. *Biophilia: The Human Bond With Other Species.* Cambridge, Mass: Harvard University Press; 1984.
14. Wilson EO. Biophilia and the conservation ethic. In: Kellert SR, Wilson EO, eds. *The Biophilia Hypothesis.* Washington, DC: Island Press; 1993:31–41.
15. Jacobs J. *The Death and Life of Great American Cities.* New York, NY: Random House; 1961.

16. Whyte WH. *The Social Life of Small Urban Spaces.* New York, NY: Conservation Foundation; 1980.

17. Whyte WH. *City: Rediscovering the Center.* New York, NY: Doubleday Books; 1988.

18. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective.* New York, NY: Cambridge University Press; 1995.

19. Kaplan R, Kaplan S, Ryan RL. *With People in Mind: Design and Management of Everyday Nature.* Washington, DC: Island Press; 1998.

20. Catalano R, Pickett KE. A taxonomy of research on place and health. In: Albrecht G, Fitpatrick R, Scrimshaw S, eds. *Handbook of Social Studies in Health and Medicine.* Thousand Oaks, Calif: Sage Publications; 2000.

21. Ulrich RS. View through a window may influence recovery from surgery. *Science.* 1984;224:420–421.

22. Lanphear BP, Byrd RS, Auinger P, Schaffer SJ. Community characteristics associated with elevated blood lead levels in children. *Pediatrics.* 1998;101: 264–271.

23. Wright RJ, Fischer EB. Putting asthma into context: community influences on risk, behavior, and intervention. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health.* New York, NY: Oxford University Press Inc; 2003: 233–262.

24. Balfour JL, Kaplan GA. Neighborhood environment and loss of physical function in older adults: evidence from the Alameda County Study. *Am J Epidemiol.* 2002;155:507–515.

25. Des Jarlais DC, Diaz T, Perlis T, et al. Variability in the incidence of human immunodeficiency virus, hepatitis B virus, and hepatitis C virus infection among young injecting drug users in New York City. *Am J Epidemiol.* 2003; 157:467–471.

26. Fullilove MT. Neighborhoods and infectious diseases. In: Kawachi I, Berkman LF, eds. *Neighborhoods and Health.* New York, NY: Oxford University Press Inc; 2003:211–222.

27. Szczygiel B, Hewitt R. Nineteenth-century medical landscapes: John H. Rauch, Frederick Law Olmsted, and the search for salubrity. *Bull Hist Med.* 2000;74:708–734.

28. Jackson RJ. What Olmsted knew. *Western City.* March 2001:12–15.

29. *Planning the Neighborhood.* Chicago, Ill: Committee on the Hygiene of Housing, American Public Health Association; 1960.

30. Dube P. Urban health: an urban planning perspective. *Rev Environ Health.* 2000;15:249–265.

31. Duhl L. Health and greening the city: relation of urban planning and health. *J Epidemiol Community Health.* 2002;56:897.

32. Northridge ME, Sclar E. A joint urban planning and public health framework: contributions to health impact assessment. *Am J Public Health.* 2003;93:118–121.

33. Jackson LE. The relationship of urban design to human health and condition. *Landscape Urban Plann.* 2003; 64(4):191-200.

34. Kearns R. Place and health: towards a reformed medical geography. *Professional Geographer.* 1993;45: 139–147.

35. Frumkin H. Beyond toxicity: the greening of environmental health. *Am J Prev Med.* 2001;20:234–240.

36. Moore EO. A prison environment's effect on health care service demands. *J Environ Syst.* 1981–1982;11:17–34.

37. Faber Taylor A, Kuo FE, Sullivan WC. Coping with ADD: the surprising connection to green play settings. *Environment Behav.* 2001;33:54–77.

38. Faber Taylor A, Kuo FE, Sullivan WC. Views of nature and self-discipline: evidence from inner city children. *J Environ Psychol.* 2002;22:49–64.

39. Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *J Epidemiol Community Health.* 2002;56:913–918.

40. Heerwagen JH. The psychological aspects of windows and window design. In: Anthony KH, Choi J, Orland B, eds. *Proceedings of the 21st Annual Conference of the Environmental Design Research Association.* Oklahoma City, Okla: Environmental Design Research Association; 1990. Cited by: Ulrich RS. Biophilia, biophobia, and natural landscapes. In: Kellert SR, Wilson EO, eds. *The Biophilia Hypothesis.* Washington, DC: Island Press; 1993:105.

41. Diette GB, Lechtzin N, Haponik E, Devrotes A, Rubin HR. Distraction therapy with nature sights and sounds reduces pain during flexible bronchoscopy: a complementary approach to routine analgesia. *Chest.* 2003;123: 941–948.

42. Kellert SR. Experiencing nature: affective, cognitive, and evaluative development in children. In: Kahn PH Jr, Kellert SR, eds. *Children and Nature: Psychological, Sociocultural, and Evolutionary Investigations.* Cambridge, Mass: MIT Press; 2002:117–151.

43. Bardana EJ Jr. Indoor pollution and its impact on respiratory health. *Ann Allergy Asthma Immunol.* 2001; 87(suppl 3):33–40.

44. Hodgson M. Indoor environmental exposures and symptoms. *Environ Health Perspect.* 2002;110(suppl 4): 663–667.

45. *Indoor Air Pollution: An Introduction for Health Professionals.* Washington, DC: US Environmental Protection Agency; 1994. EPA publication 1994-523-217/ 81322.

46. Bearg DW. *Indoor Air Quality and HVAC Systems.* Chelsea, Mich: Lewis Publishers; 1993.

47. Seppanen O, Fisk WJ. Association of ventilation system type with SBS symptoms in office workers. *Indoor Air.* 2002;12:98–112.

48. Wargocki P, Sundell J, Bischof W, et al. Ventilation and health in non-industrial indoor environments: report from a European multidisciplinary scientific consensus meeting (EUROVEN). *Indoor Air.* 2002;12:113–128.

49. *Sustainable Architecture White Papers.* New York, NY: Earth Pledge Foundation; 2001.

50. Stitt F. *The Ecological Design Handbook.* New York, NY: McGraw-Hill Book Co; 1999.

51. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, Ga: Centers for Disease Control and Prevention; 1996.

52. Boyce PR. *Human Factors in Lighting.* London, England: Applied Science Publishers; 1981.

53. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health.* 2002;92: 758–768.

54. Thomson H, Petticrew M, Douglas M. Health impact assessment of housing improvements: incorporating research evidence. *J Epidemiol Community Health.* 2003;57:11–16.

55. Ulrich RS, Addoms DL. Psychological and recreational benefits of a residential park. *J Leisure Res.* 1981;13: 43–65.

56. Kuo FE, Sullivan WC, Coley RL, Brunson L. Fertile ground for community: inner-city neighborhood common spaces. *Am J Community Psychol.* 1998; 26:823–851.

57. Burden D. *Street Design Guidelines for Healthy Neighborhoods.* Sacramento, Calif: Local Government Commission; 1999.

58. Altman I, Zube E, eds. *Public Places and Spaces.* New York, NY: Plenum Press; 1989.

59. Garvin A, Berens G. *Urban Parks and Open Space.* Washington, DC: Urban Land Institute and Trust for Public Land; 1997.

60. Marcus CC, Watsky CM, Insley E, Francis C. Neighborhood parks. In: Marcus CC, Francis C, eds. *People Places: Design Guidelines for Urban Open Space.* 2nd ed. New York, NY: John Wiley & Sons Inc; 1998:85–148.

61. Francis M. Some meanings attached to a city park and community gardens. *Landscape J.* 1987;6:101–112.

62. Burgess J, Harrison CM, Lamb M. People, parks and the urban green: a study of popular meanings and values for open spaces in the city. *Urban Stud.* 1988;25:455–473.

63. Loukaitou-Sideris A. Urban form and social context: cultural differentiation in the uses of urban parks. *J Plann Educ Res.* 1995;14:89–102.

64. Sallis JF, Baumann A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med.* 1998;15:379–397.

65. Brownson RC, Baker EA, Housemann RA, Brennan LK, Bacak SJ. Environmental and policy determinants of physical activity in the United States. *Am J Public Health.* 2001;91: 1995–2003.

66. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med.* 2002;22: 188–199.

67. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002;23(suppl 2):64–73.

68. Craig CL, Brownson RC, Cragg SE, Dunn AL. Exploring the effect of the environment on physical activity: a study examining walking to work. *Am J Prev Med.* 2002;23(suppl 2):36–43.

69. Glynn T. Psychological sense of community: measurement and application. *Hum Relations.* 1981;34:789–818.

70. Leyden K. Social capital and the built environment: the importance of walkable neighborhoods. *Am J Public Health.* 2003;93:1546–1551.

71. Lund H. Pedestrian environments and sense of community. *J Plann Educ Res.* 2002;21:301–312.

72. Skjaeveland O, Garling T. Effects of interactional space on neighboring. *J Environ Psychol.* 1997;17:181–198.

73. Gillham O. *The Limitless City: A Primer on the Urban Sprawl Debate.* Washington, DC: Island Press; 2002.

74. Ewing R, Pendall R, Chen D. *Mea-*

suring Sprawl and Its Impact. Washington, DC: Smart Growth America; 2002.

75. Wilson WJ. *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy.* Chicago, Ill: University of Chicago Press; 1987.

76. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002; 117:201–217.

77. Andrulis DP. The urban health penalty: new dimensions and directions in inner-city health care. Available at: http://www.acponline.org/hpp/pospaper/andrulis.htm. Accessed June 21, 2003.

78. Andrulis DP, Ginsberg C, Shaw-Taylor Y, Martin V. *Urban Social Health.* Washington, DC: National Public Health and Hospital Institute; 1995.

79. Andrulis DP, Goodman NJ. *The Social and Health Landscape of Urban and Suburban America.* Chicago, Ill: American Hospital Association; 1999.

80. Ford AB. *Urban Health in America.* New York, NY: Oxford University Press Inc; 1997.

81. McCarthy M. Social determinants and inequalities in urban health. *Rev Environ Health.* 2000;15:97–108.

82. Douglas MJ, Conway L, Gorman D, Gavin S, Hanlon P. Developing principles for health impact assessment. *J Public Health Med.* 2001;23:148–154.

83. Frankish CJ, Green LW, Ratner PA, Chomik T, Larsen C. *Health Impact Assessment as a Tool for Health Promotion and Population Health.* Geneva, Switzerland: World Health Organization; 2001: 405–437.

84. Joffe M, Mindell J. A framework for the evidence base to support health impact assessment. *J Epidemiol Community Health.* 2002;56:132–138.

85. Lock K. Health impact assessment. *BMJ.* 2000;320:1395–1398.

86. McCarthy M, Biddulph JP, Utley M, Ferguson J, Gallivan S. A health impact assessment model for environmental changes attributable to development projects. *J Epidemiol Community Health.* 2002;56:611–616.

A Review of Evidence-Based Traffic Engineering Measures Designed to Reduce Pedestrian–Motor Vehicle Crashes

We provide a brief critical review and assessment of engineering modifications to the built environment that can reduce the risk of pedestrian injuries.

In our review, we used the Transportation Research Information Services database to conduct a search for studies on engineering countermeasures documented in the scientific literature. We classified countermeasures into 3 categories—speed control, separation of pedestrians from vehicles, and measures that increase the visibility and conspicuity of pedestrians. We determined the measures and settings with the greatest potential for crash prevention.

Our review, which emphasized inclusion of studies with adequate methodological designs, showed that modification of the built environment can substantially reduce the risk of pedestrian–vehicle crashes. (*Am J Public Health.* 2003;93:1456–1463)

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DESPITE DECLINING RATES OF pedestrian fatalities (most notably declines among children and older adults), pedestrian crash injuries remain a serious public health problem. It is estimated that, each year, 80 000 to 120 000 pedestrians are injured and 4600 to 4900 die in motor vehicle crashes in the United States.[1,2] Pedestrians account for 11% of all motor vehicle deaths, and in cities with populations exceeding 1 million, they account for about 35%.[3] Children aged 5 to 9 years have the highest population-based injury rate, and people older than 80 years have the highest population-based fatality rate.[1] Pedestrians older than 65 years are more likely than younger pedestrians to be struck at intersections.[3,4] The prevalence of alcohol use among injured pedestrians is well documented.[5–7]

In terms of constructing a framework for prevention of pedestrian injuries, primary approaches include modification of the built environment, enforcement of traffic safety laws, motor vehicle design changes, and pedestrian education. Modification of car fronts and other vehicle features to reduce the severity of injuries to pedestrians is a focus in Europe, where approximately 20% of all fatalities among road users involve pedestrians and cyclists[8]; however, this approach has not been a priority in the United States despite research showing potential benefits.[9]

Pedestrian education is a popular approach, but with the exception of children, there is a lack of evidence regarding the effectiveness of safety education.[10–12] Modification of the built environment is a widely used approach that can be highly effective. In this article, we provide a brief review of engineering modifications to the built environment that can reduce the risk and severity of pedestrian injuries.

TRAFFIC ENGINEERING COUNTERMEASURES

Pedestrians have been largely ignored or given minimal consideration in the design of much of the nation's roadway system. When the built environment assigns low priority to pedestrians, it can be difficult for vehicles and pedestrians to share the road safely. Modifications to the built environment can reduce the risk and severity of vehicle–pedestrian crashes. Engineering modifications generally can be classified into 3 broad categories: separation of pedestrians from vehicles by time or space, measures that increase the visibility and conspicuity of pedestrians, and reductions in vehicle speeds.

Separation countermeasures reduce the exposure of pedestrians to potential harm both on the roadside and when they are crossing streets. Because in many pedestrian crashes the driver reportedly does not see the pedestrian before the accident, measures are needed to increase the visibility and conspicuity of pedestrians. Higher vehicle speeds are strongly associated with a greater likelihood of crashes involving pedestrians as well as more serious pedestrian injuries.[13–15]

We undertook a thorough review of traffic engineering countermeasures documented in the scientific literature as effective in reducing the risk of crashes involving pedestrians. The primary search engine used was the National Academy of Sciences' Transportation Research Information Services (TRIS) database. TRIS is the world's largest and most comprehensive bibliographic resource on transportation information. Keywords were *pedestrians* along with *injuries*, *safety*, *reduction*, *countermeasures*, and *crosswalks*. In terms of study types, we included before–after, case–control, and cross-sectional studies of the effects of speed reduction, separation, or visibility enhancement measures on the occurrence of pedestrian–vehicle collisions or conflicts.

Many studies of traffic engineering measures are limited by methodological flaws such as failure to account for regression to the mean associated with treatment of high-crash locations and reliance on simple before–after measurements without suitable controls. To the extent possible, we included in our review studies based on adequate scientific criteria, such as use of comparison sites to control for confounding factors. In the case of several promising countermeasures, only limited evaluations with somewhat less reliable methodologies were available.

A common weakness in many crash-based before-and-after evaluations of traffic engineering countermeasures is failure to account for regression to the mean, which can result in overestimation of the effects of an intervention when treatment sites are selected because they have involved high numbers of crashes. Selection of comparison sites with similar characteristics can partially, but not fully, address regression to the mean. We included in our review several studies with methodological weaknesses; in these cases, we make note of their limitations.

Some researchers conducting observational road safety studies evaluate pedestrian–motor vehicle conflicts in lieu of crash data to evaluate roadway countermeasures, in part because crashes are rare events and because conflict studies provide information about potential crash causes. Conflicts generally are defined as "near-miss" situations in which a vehicle had to abruptly brake or swerve to avoid striking a pedestrian or a pedestrian had to take sudden evasive action to avoid being struck. The validity of using conflicts to estimate crashes was examined by Hauer and Garder[16] and Garder.[17] Hauer and Garder formulated and tested statistical methods to measure the validity of traffic conflicts on the basis of empirical evidence. According to Garder, it can be shown that a 1-day conflict count provides a more accurate estimate of the expected number of crashes than a 1-year crash history if the expected number of crashes is less than 5 per year. In conflict studies and other short-term before–after evaluations of road user behavior, regression to the mean associated with treatment of high-crash locations is not a factor.

Managing Vehicle Speeds

Principal engineering measures designed to reduce vehicle speeds are summarized in Table 1. In residential settings with large numbers of children, speed management appears to offer the greatest potential for injury prevention. Pedestrian crashes involving a child most often result from the child's error. Slower speeds give motorists more time to react and can lessen injuries when crashes do occur. Slower speeds are desirable in areas with pedestrians because many young children fail to stop before proceeding from the curb onto the road[24]; Kraus et al.[25] reported that 69% of child pedestrian injuries occur midblock, when children dart into the street. Young children have difficulty judging vehicle distance and velocity[26] and lack the relevant cognitive skills required to make valid and consistent crossing judgments.[27]

In terms of crash reduction, installation of modern roundabouts in place of conventional intersections was the most effective speed control intervention identified. Roundabouts are circular intersections defined by 2 operational and design principles: yield at entry, which requires entering traffic to yield the right of way to vehicles in the circle, and deflection of entering traffic, which causes vehicles to enter at low speed. European studies indicate that, on average, converting conventional intersections to roundabouts can reduce the rate of pedestrian crashes by about 75%.[18,19] Single-lane roundabouts, in particular, have been reported to involve substantially lower pedestrian crash rates than comparable intersections with traffic signals.[20]

Other speed management measures include traffic calming and multiway stop sign control. Traffic calming techniques include lane narrowing, adjustments in roadway curvature, pedestrian refuge islands, and speed humps. Although traffic calming measures clearly are effective in reducing traffic speeds (e.g., see Smith and Appleyard[28]), effects on pedestrian–vehicle crashes are less certain. One study of "extensive" area-wide traffic calming measures, involving a before–after design without controls, reported that pedestrian–vehicle crashes decreased 25% after implementation of these measures.[21] However, a recent review of 13 controlled before–after studies of area-wide traffic calming reported no overall effect on pedestrian–vehicle crashes.[22] An investigation focusing on multiway stop sign control, which produces low vehicle speeds near intersections relative to traffic signal control or conventional 2-way stop signs, showed that pedestrian collisions decreased by 25% when multiway stop signs were installed in place of traffic signals at low-traffic-volume urban intersections.[23]

Separating Pedestrians and Vehicles

Engineering measures intended to separate pedestrians and vehicles by *time* are summarized in Table 2. These interventions have generally been evaluated in terms of their effects on road user behavior and pedestrian–vehicle conflicts rather than crashes, and their use is somewhat site dependent. One study reported that installation of traffic signals substantially reduced conflicts occurring at high-speed intersections where previously no signals were present and pedestrians had difficulty crossing.[30] At intersections with traffic signals, exclusive traffic signal phasings—which stop all vehicle traffic for part or all of the pedestrian crossing signal—have been shown to significantly reduce conflicts.[30,31] A comparative analysis of intersections with and without exclusive pedestrian

TABLE 1—Studies Evaluating Engineering Measures Designed to Manage Vehicle Speeds

Intervention	Study and Country	Outcome Measures	Study Design	Results
Modern roundabouts	Brilon et al., Germany[18]	Pedestrian–vehicle crashes	Before-and-after with data on traffic volume before and after; 25 intersections converted from traffic signals or stop signs to modern roundabouts; no attempt to correct findings for possible regression-to-mean effects	On average, pedestrian crashes decreased 75%
	Schoon and van Minnen, the Netherlands[19]	Pedestrian–vehicle crashes	Before-and-after without control; 181 intersections converted from traffic signals or stop signs to modern roundabouts; no attempt to correct findings for possible regression-to-mean effects	On average, pedestrian–vehicle crashes decreased 73%
	Brude and Larsson, Sweden[20]	Pedestrian–vehicle crashes	Observed minus expected: empirical data for 72 roundabouts as compared with expected values for comparable intersections with signals, controlling for pedestrian volumes and traffic flow; multiple linear regression used to predict crashes for comparison data	For single-lane roundabouts, the observed number of pedestrian crashes was 3–4 times lower than predicted for comparable intersections with signals; for 2-lane roundabouts, pedestrian crash risk was comparable to signalized intersections
Traffic calming	Brilon and Blanke, Germany[21]	Pedestrian–vehicle crashes	Before-and-after without control; "extensive" area-wide traffic calming measures implemented in 6 towns	On average, pedestrian–vehicle crashes decreased 25% after treatment
	Bunn et al., Australia, Germany, United Kingdom[22]	Pedestrian–vehicle crashes	Systematic review of 13 controlled before–after studies of area-wide traffic calming with pedestrian–vehicle crash data	Pooled rate ratio was 1.00, indicating no effect on pedestrian–vehicle crashes
Multiway stop-sign control	Persaud et al. United States[23]	Pedestrian–vehicle crashes	Before-and-after using empirical Bayesian procedure; 199 low-traffic-volume urban intersections converted from traffic signals to multiway stop-sign control	Pedestrian–vehicle crashes decreased by approximately 25%

signal phasings reported that the risk of pedestrian–vehicle crashes at intersections with exclusive timing was approximately half that at intersections with standard pedestrian signals.[29]

Adequately timed yellow and all-red clearance signals are necessary at traffic signals to ensure that drivers have sufficient time to clear the intersection before the display of pedestrian walk signals. One study showed that combined changes in the duration of yellow and all-red signal timing reduced the risk of pedestrian and bicycle crashes at intersections by 37% relative to control sites.[32] Automatic pedestrian detection, which can be used at traffic signals in lieu of pedestrian push buttons to automatically detect pedestrians and display a walk signal, has been reported to significantly reduce conflicts.[34] This technology also can extend crossing time to allow slower pedestrians to finish crossing. At intersections with traffic signals and high concentrations of elderly pedestrians, a walking speed of 1.0 m/second is recommended.[37]

Also, traffic signs and pavement markings that encourage pedestrians to look for potential conflicts have been shown to be effective at intersections with traffic signals.[33] In addition, 2 studies showed that vehicle speeds and conflicts at uncontrolled crossings were reduced by in-pavement flashing lights that were automatically activated by the presence of pedestrians and were intended to prompt drivers to yield to pedestrians.[35,36]

Engineering measures designed to separate pedestrians and vehicles by *space* are summarized in Table 3. Several highly effective interventions were identified. Overpasses and underpasses can substantially reduce conflicts and associated pedestrian crashes.[38] However, the high cost of such facilities requires that they be installed on a very limited basis—for example, at very wide crossings and at those with high traffic speeds. Safety effects may be limited in instances in which pedestrians are reluctant to use such facilities because of security concerns or inconvenient access points. Sidewalks can reduce the risk of pedestrian crashes in residential areas.[42]

Refuge islands located in the medians of 2-way streets allow pedestrians to cross in 2 stages, simplifying the crossing task. This is especially helpful for pedestrians who walk at slower speeds. Refuge islands decrease conflicts,[30] and there are significantly lower pedestrian crash rates on multilane roads with raised medians than on those without such medians.[43] Curb extensions (extension of the sidewalk toward the roadway in the vicinity of the crosswalk, about the width of a parked vehicle) also can be used to reduce crossing distance.

Barriers and fences, which are designed to channel pedestrians

TABLE 2—Studies Evaluating Engineering Measures Designed to Separate Pedestrians and Vehicles by Time

Intervention	Study and Country	Outcome Measures	Study Design	Results
Exclusive pedestrian signal phase	Zegeer et al., United States[29]	Pedestrian–vehicle crashes	Comparative analysis approach including analysis of variance and covariance using data from 1297 intersections with signals in 15 cities; control for number of lanes, type of traffic signal, signal timing, speed limits, traffic volume, pedestrian exposure, and other variables	Risk of pedestrian–vehicle crashes for intersections with exclusive timing was approximately half that of intersections with standard pedestrian signals
	Garder, Sweden[30]	Pedestrian–vehicle conflicts	Before-and-after without controls; 3 urban intersections	At one intersection in a small town, conflicts decreased 24%; in Stockholm, at one intersection conflicts decreased 10% but did not significantly decline at a second intersection
Early release signal timing, also known as leading pedestrian interval (LPI)	Van Houten et al., United States[31]	Pedestrian–vehicle conflicts; pedestrians yielding to turning vehicles; distance traversed by lead pedestrian	Multiple-baseline design; 3 urban intersections	For pedestrians leaving the curb during the begin walk period, odds of conflict with turning vehicles were reduced by 95%; odds of pedestrians yielding to turning vehicles were reduced by 60%; mean distance traversed by the lead pedestrian during the LPI was 8.5 ft
Installation of traffic signal	Garder, Sweden[30]	Pedestrian–vehicle conflicts	Multiple linear regression model using data from 115 urban intersections; variables included type of traffic control, street width, existence of refuge island, traffic speeds, and exposure	Installation of traffic signal at a high-speed (mean speed > 30 km/h) intersection reduced the risk of pedestrian–vehicle conflicts by roughly half
Traffic signal change interval timing	Retting et al., United States[32]	Pedestrian/bicycle–vehicle crashes	Randomized before-and-after with controls; 40 experimental urban intersections and 51 controls	During 3 years after study period, there was a 37% reduction in pedestrian and bicycle crashes relative to controls
Pedestrian prompting devices	Retting et al., United States and Canada[33]	Pedestrians looking for potential vehicle threats; pedestrian–vehicle conflicts	Multiple-baseline design; 3 urban intersections	One year after treatment, percentage of pedestrians looking for potential vehicle threats doubled at 2 sites and tripled at 1 site; pedestrian–vehicle conflicts per 100 pedestrians declined at all 3 sites, from approximately 2.8 to < 1
Automatic pedestrian detection for display of walk signal	Hughes et al., United States[34]	Pedestrians who began to cross during the "don't walk" signal; pedestrian–vehicle conflicts	Before-and-after without controls; 4 urban intersections (conflicts were not studied at 1 site owing to visual limitations)	At 4 sites, reductions in the percentage of pedestrians who began to cross during the "don't walk" signal ranged from 52% to 88%; at 3 sites, reductions in the percentage of pedestrian–vehicle conflicts ranged from 40% to 90%
In-pavement flashing lights to warn drivers when pedestrians are present	Hakkert et al., Israel[35]	Vehicle speeds; drivers yielding to pedestrians; vehicle–pedestrian conflicts	Before-and-after without controls; 4 urban uncontrolled pedestrian crossings	Although changes were not uniform, overall effects were positive; vehicle speeds near crosswalks decreased slightly at 2 sites (2–5 kph); at 3 sites, the rate of drivers yielding to pedestrians doubled; across all sites, rate of conflicts decreased to less than 1% from 1% to 17%
	Prevedouros, United States[36]	Vehicle speeds, percentage of drivers who slowed or stopped; percentage of drivers not yielding to pedestrians in crosswalk	Before-and-after without controls; 1 urban uncontrolled pedestrian crossing	Average vehicle speeds declined 25% when in-pavement lights were activated; percentage of drivers who slowed or stopped for pedestrians increased from 30% to 62%; percentage of drivers not yielding to pedestrians declined from 31% to 8%

TABLE 3—Studies Evaluating Engineering Measures Designed to Separate Pedestrians and Vehicles by Space

Intervention	Study and Country	Outcome Measures	Study Design	Results
Pedestrian overpasses	Japan Road Association, Japan[38]	Pedestrian–vehicle crashes	Before-and-after without control; 31 pedestrian overpasses in urban areas; data limited to 6 months before and 6 months after intervention; no attempt to correct findings for possible regression-to-mean effects	Number of pedestrian–vehicle crashes decreased 91% within 100 m of the structures and 85% within 200 m; crashes unrelated to pedestrians crossing the road increased 14% within 100 m of the structures and 23% within 200 m
Advance stop lines	Berger, United States[39]	Distance of stopped vehicles from crosswalk	Before-and-after with control; stop lines were relocated 12 ft back from the standard 3–4-ft distance at 2 urban intersections with signals	Distance of stopped vehicles from the crosswalks increased by approximately 6 ft at one site and 7 ft at the other site (percentage change could not be readily computed from available documentation)
	Retting and Van Houten, United States[40]	Driver compliance with stop lines; percentage of drivers stopping at least 4 ft back from crosswalks; drivers stopping in crosswalks	Before-and-after without control; stop lines were relocated 20 ft back from the standard 4-ft distance at 4 urban intersections with signals	Overall, approximately 57% of drivers complied with advance stop lines; percentage of drivers who stopped at least 4 ft back from the crosswalks increased from 74% to 92%; percentage of drivers who stopped within crosswalks during any portion of the "walk" and pedestrian clearance phases declined from 25% to 7%
Pedestrian barriers and fences	Berger, United States[39]	Pedestrians crossing midblock	Before-and-after with control; 2 urban arterial streets with high traffic volumes in close proximity to elementary schools	In both cities, significant decreases were observed in number of pedestrians crossing midblock and entering roadway in front of parked vehicles (percentage change could not be readily computed from available documentation)
	Stewart, England[41]	Pedestrian–vehicle crashes	Before-and-after without control; unknown number of locations; no attempt to correct findings for possible regression-to-mean effects	Ordinary fences, which obscure the driver's view of pedestrians, were associated with 20% reduction in pedestrian crashes, whereas fences that obstructed the motorist's view to a lesser extent led to a 48% crash reduction; children (because of their short stature) especially benefited from fences that obstructed motorist's view to a lesser extent
Sidewalks	Knoblauch et al., United States[42]	Pedestrian–vehicle crashes	Cross-sectional study of urban streets with and without sidewalks; data from 495 locations in 5 cities (16 hours of exposure data collected at each site); variables included land use, pedestrian–vehicle crashes, and exposure measures	In residential and mixed residential areas, pedestrian crashes were more than 2 times as likely to occur at locations without sidewalks than would be expected on the basis of exposure; residential areas with no sidewalks had 23% of all pedestrian–vehicle crashes and only 3% of exposures; commercial areas with no sidewalks were only slightly more hazardous than commercial areas with sidewalks
Refuge islands	Garder, Sweden[30]	Pedestrian–vehicle conflicts	Multiple linear regression; data from 115 urban intersections; variables included type of traffic control, street width, existence of refuge island, and exposure	Risk of pedestrian–vehicle conflicts decreased by roughly two thirds
	Zegeer et al., United States[43]	Pedestrian–vehicle crashes	Cross-sectional study: Poisson and negative binomial regression models fitted to crash data at 1000 marked crosswalk sites and 1000 matched unmarked comparison sites; controlled for traffic volume, pedestrian exposure, number of lanes, type of median, and other variables	On roads with >2 lanes and >15 000 vehicles per day, pedestrian crash rate (per million crossings) at marked crossings with raised medians was approximately half that of locations without raised medians; crash rate at unmarked crossings with raised medians was approximately 60% that of unmarked crossings without raised medians

to safe crossing areas and prevent them from running into traffic, have been found to reduce midblock crossings[39] and substantially decrease crash rates.[41] An inexpensive intervention at signal-controlled intersections involves repositioning of stop lines further back from crosswalks. This results in drivers stopping further back from crosswalks, thus increasing the separation between pedestrians and vehicles.[39,40]

Increasing Pedestrian Visibility

Engineering measures designed to increase the visibility and conspicuity of pedestrians are summarized in Table 4. Increased intensity of roadway lighting can increase pedestrians' visibility at night, when more than half of all fatal pedestrian crashes occur.[1] Increased intensity of roadway lighting at pedestrian crossings has been associated with significant reductions in nighttime pedestrian crashes.[44,45]

Because parked vehicles obscure the vision of pedestrians and drivers, parking restrictions can be effective. In a case–control study of child pedestrian injuries, the number of parked vehicles was the strongest risk factor on residential streets.[47] Examples of parking restrictions include removal of on-street parking and implementation of diagonal parking, which requires that vehicles park at an

TABLE 4—Studies Evaluating Engineering Measures Designed to Increase Visibility and Conspicuity of Pedestrians

Intervention	Study and Country	Outcome Measures	Study Design	Results
Increased intensity of roadway lighting	Pegrum, Australia[44]	Nighttime pedestrian–vehicle crashes	Before-and-after at 57 urban crosswalks; daytime crashes were used as controls for nighttime crashes; 2 years before and after; no attempt to correct findings for possible regression-to-mean effects	Number of nighttime pedestrian crashes decreased 59%; daytime pedestrian crashes and vehicle-only crashes remained relatively unchanged
Increased intensity of roadway lighting and installation of internally illuminated warning signs	Polus and Katz, Israel[45]	Nighttime pedestrian–vehicle crashes	Before-and-after with control; 99 urban crosswalks; 39 control sites; daytime crashes also used as controls; 2.5 years before and after; no attempt to correct findings for possible regression-to-mean effects	Number of nighttime pedestrian crashes at the experimental sites decreased 57%, and there was a nonsignificant 21% decrease in daytime pedestrian crashes; at the comparison sites, there was a nonsignificant 60% increase in nighttime pedestrian crashes
Bus stop relocation	Berger, United States[39]	Pedestrians entering roadway in front of stopped bus	Before-and-after with control; 1 bus stop was relocated from the near side to the far side of a traffic-signal-controlled intersection on a 2-way 5-lane urban arterial (the intervention was tested in a second city but with very small samples)	Significant decrease was observed in percentage of pedestrians entering roadway in front of a stopped bus (percentage change could not be readily computed from available documentation)
Diagonal parking	Berger, United States[39]	Pedestrians entering roadway in front of parked vehicle; pedestrians who scanned for traffic before entering roadway	Before-and-after without control; diagonal parking replaced parallel parking on a 34-ft-wide 1-way, 2-lane urban street (the intervention was tested in a second city but with very small samples)	Number of pedestrians entering roadway in front of a parked vehicle significantly decreased, and percentage of pedestrians who scanned for traffic before entering the roadway significantly increased; vehicle speeds significantly decreased by 5 mph (percentage change could not be readily computed from available documentation)
Crosswalk markings	Zegeer et al., United States[43]	Pedestrian–vehicle crashes	Cross-sectional study: treatment and matched comparison; regression models fitted to crash data at 1000 marked crosswalk sites and 1000 matched unmarked comparison sites	On 2-lane roads, marked crosswalk was associated with no difference in pedestrian crash rate; on wider roads with traffic volumes > 12 000 vehicles per day, marked crosswalks were associated with higher pedestrian crash rates
	Koepsell et al., United States[46]	Pedestrian–vehicle crashes	Case–control study of crashes involving older pedestrians (> 65 years) in 6 cities; 282 case sites and 564 control sites; adjusted for pedestrian flow, traffic volume, crossing length, and signalization	Crash risk was 2.1 times greater at sites with a marked crosswalk; almost all of the excess risk was due to 3.6-fold higher risk associated with marked crosswalks at sites with no traffic signal or stop sign

angle to the curb (typically about 30 degrees) in the direction of traffic flow. Diagonal parking directs pedestrians into the roadway at such an angle that looking in the direction of traffic is universal. Diagonal parking as a replacement for parallel parking has been shown to reduce the number of pedestrians entering the roadway in front of a parked vehicle.[39]

In addition, relocating bus stops from the near side to the far side of intersections can increase the visibility and conspicuity of pedestrians by decreasing the number of pedestrians who enter the roadway in front of a stopped bus. It has been shown that bus stop relocation significantly decreases the percentage of pedestrians who enter the roadway in front of a stopped bus at signal-controlled intersections.[39] Crosswalk pavement markings are widely used with the intent of reducing pedestrian crashes, but research indicates that they are largely ineffective and, in some settings, may be harmful.[43,46]

DISCUSSION

Pedestrian crashes are complex events that vary widely in terms of the age of the pedestrians involved and associated crash circumstances. According to our review of available studies, emphasizing those with adequate methodological designs, modification of the built environment can substantially reduce the risk of pedestrian–vehicle crashes. Given the scarcity of resources generally available for road engineering and the very large number of roads, priority must be given to the specific countermeasures and settings with the greatest potential for crash prevention.

Highly effective countermeasures include single-lane roundabouts, sidewalks, exclusive pedestrian signal phasing, pedestrian refuge islands, and increased intensity of roadway lighting. Other countermeasures, including advance stop lines, in-pavement flashing lights, and automatic pedestrian detection at walk signals, are promising but have been evaluated on a more limited basis. In the case of many traffic engineering measures, more definitive research is needed to establish their effects on pedestrian–vehicle crash risks. ■

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References

1. *Traffic Safety Facts 2001.* Washington, DC: National Highway Traffic Safety Administration; 2002.

2. *National Electronic Injury Surveillance System—All Injury Program Operated by the US Consumer Product Safety Commission.* Atlanta, Ga: National Center for Injury Prevention and Control; 2002.

3. Insurance Institute for Highway Safety. Fatality facts 2001: pedestrians. Available at: http://www.hwysafety.org/safety_facts/fatality_facts/pedestrians.pdf. Accessed January 31, 2003.

4. Knoblauch R, Nitzburg M, Dewar R, Templer J, Pietrucha M. *Older Pedestrian Characteristics for Use in Highway Design.* Washington, DC: US Dept of Transportation; 1995. DOT publication FHWA-RD-93-177.

5. McCarroll JR, Braunstein PW, Cooper W, et al. Fatal pedestrian automotive accidents. *JAMA.* 1962;180:127–133.

6. Curtin D, Syner J, Vegega M. Alcohol involvement in pedestrian fatalities—United States, 1982–1992. *MMWR Morb Mortal Wkly Rep.* 1993;42:716–719.

7. Vestrup JA, Reid JDS. A profile of urban adult pedestrian trauma. *J Trauma.* 1989;29:741–745.

8. Hobbs A. *Safer Car Fronts for Pedestrians and Cyclists.* Brussels, Belgium: European Transport Safety Council; 2001.

9. *Vehicle Designs Affect the Harm That's Inflicted on Pedestrians.* Arlington, Va: Insurance Institute for Highway Safety; 1999:4–5. Status report 34/3.

10. O'Neill B, Mohan D, Breen J, et al. Commentary on the World Bank's Global Road Safety Partnership. *Traffic Inj Prev.* 2002;3:190–194.

11. Duperrex O, Bunn F, Roberts I. Safety education of pedestrians for injury prevention: a systematic review of randomized controlled trials. *BMJ.* 2002;324:1129–1133.

12. Weiner EL. The elderly pedestrian: response to an enforcement campaign. *Traffic Safety Res Rev.* 1968;11:100–110.

13. Pitt R, Guyer B, Hsieh C, Malek M. The severity of pedestrian injuries in children: an analysis of the Pedestrian Injury Causation Study. *Accid Anal Prev.* 1990;22:549–559.

14. Pasanen E, Salmivaara H. Driving speeds and pedestrian safety in the city of Helsinki. *Traffic Eng Control.* June 1993:308–310.

15. Leaf WA, Preusser DF. *Literature Review on Vehicle Speeds and Pedestrian Injuries.* Washington, DC: US Dept of Transportation; 1999. DOT publication HS 809 021.

16. Hauer E, Garder P. Research into the validity of the traffic conflicts technique. *Accid Anal Prev.* 1986;18:471–481.

17. Garder P. Theory for strong validation, application of Swedish results. In: *Proceedings From Evaluation 85: International Meeting on the Evaluation of Local Traffic Safety Measures.* Paris, France: Organisation National de Securite Routiere; 1985.

18. Brilon W, Stuwe B, Drews O. *Sicherheit und Leistungsfahigkeit von Kreisverkehrsplatzen.* Bochum, Germany: Lehrstuhl fur Verkehrswesen, Ruhr-Universitat Bochum; 1993. Cited by: Elvik R. Effects on road safety of converting intersections to roundabouts: a review of evidence from non-US studies. *Transportation Res Rec.* In press.

19. Schoon C, van Minnen J. The safety of roundabouts in the Netherlands. *Traffic Eng Control.* March 1994:142–148.

20. Brude U, Larsson J. What roundabout design provides the highest possible safety? *Nordic Road Transport Res.* 2000;12:17–21.

21. Brilon W, Blanke H. Extensive traffic calming: results of the accident analyses in six model towns. In: *Proceedings of the 63rd Annual Meeting of the Institute of Transportation Engineers.* Washington, DC: Institute of Transportation Engineers; 1993:119–123.

22. Bunn F, Collier T, Frost C, Ker K, Roberts I, Wentz R. *Area-Wide Traffic Calming for Preventing Traffic Related Injuries.* Oxford, England: Update Software; 2003.

23. Persaud B, Hauer E, Retting RA, Vallurupalli R, Mucsi K. Crash reductions related to traffic signal removal in Philadelphia. *Accid Anal Prev.* 1997;29:803–810.

24. Zeedyk MS, Wallace L, Spray L. Stop, look, listen and think? What young children really do when crossing the road. *Accid Anal Prev.* 2002;34:43–50.

25. Kraus JF, Hooten EG, Brown KA, Peek-Asa C, Heye C, McArthur D. Child pedestrian and bicyclist injuries: results of community surveillance and a case-study control. *Inj Prev.* 1996;2:212–218.

26. Phinney J, Colker L, Cosgrove M. *Literature Review on the Preschool Pedestrian.* Washington, DC: US Dept of Transportation; 1985. DOT publication HS-806-679.

27. Embry DD, Malfetti JM. *Stay Out of the Street! Reducing the Risk of Pedestrian Accidents to Preschool Children Through Parent Training and Symbolic Modeling.* Falls Church, Va: AAA Foundation for Traffic Safety; 1981. Safe Playing Project report 2.

28. Smith DT Jr, Appleyard D. *Improving the Residential Street Environment—Final Report.* Washington, DC; US Dept of Transportation; 1981. DOT publication FHWA-RD-81/031.

29. Zegeer CV, Opiela KS, Cynecki MJ. Effect of pedestrian signals and signal timing on pedestrian accidents. *Transportation Res Rec.* 1982;847:62–72.

30. Garder P. Pedestrian safety at traffic signals: a study carried out with the help of a traffic conflicts technique. *Accid Anal Prev.* 1989;21:435–444.

31. Van Houten R, Retting RA, Farmer

C, Van Houten J. Field evaluation of a leading pedestrian interval signal phase at three urban intersections. *Transportation Res Rec.* 2000;1734:86–92.

32. Retting RA, Chapline JF, Williams AF. Changes in crash risk following retiming of traffic signal change intervals. *Accid Anal Prev.* 2002;34:215–220.

33. Retting RA, Van Houten R, Malenfant L, Van Houten J, Farmer CM. Special signs and pavement markings improve pedestrian safety. *ITE J.* 1996;66: 28–35.

34. Hughes R, Huang H, Zegeer C, Cynecki M. Automated detection of pedestrians in conjunction with standard pedestrian push buttons at signalized intersections. *Transportation Res Rec.* 2000;1705:32–39.

35. Hakkert AS, Gitelman V, Ben-Shabat E. An evaluation of crosswalk warning systems. In: *Proceedings of the 80th Annual Meeting of the Transportation Research Board* [CD-ROM]. Washington, DC: Transportation Research Board; 2001.

36. Prevedouros PD. Evaluation of in-pavement flashing lights on a six-lane arterial pedestrian crossing. In: *Proceedings of the 71st Annual Meeting of the Institute of Transportation Engineers* [CD-ROM]. Washington, DC: Institute of Transportation Engineers; 2001.

37. Coffin A, Morrall J. Walking speeds of elderly pedestrians at crosswalks. *Transportation Res Rec.* 1995;1487: 63–67.

38. *Accident Prevention Effects of Road Safety Devices.* Tokyo, Japan: Japan Road Association; 1969.

39. Berger WG. *Urban Pedestrian Accident Countermeasures Experimental Evaluation: Volume 1—Behavioral Studies.* Washington, DC: US Dept of Transportation; 1975. DOT publication HS-801-346.

40. Retting RA, Van Houten R. Safety benefits of advance stop lines at signalized intersections: results of a field evaluation. *ITE J.* 2000;70:47–54.

41. Stewart D. Pedestrian guard rails and accidents. *Traffic Eng Control.* 1988;29:450–455.

42. Knoblauch RL, Tustin BH, Smith SA, Pietrucha MT. *Investigation of Exposure-Based Pedestrian Accident Areas: Crosswalks, Sidewalks, Local Streets, and Major Arterials.* Washington, DC: US Dept of Transportation; 1987. DOT publication FHWA-RD-87-038.

43. Zegeer CV, Stewart JR, Huang H, Lagerwey P. Safety effects of marked versus unmarked crosswalks at uncontrolled locations. *Transportation Res Rec.* 2001;1723:56–68.

44. Pegrum BV. The application of certain traffic management techniques and their effect on road safety. In: *Proceedings of the National Road Safety Symposium.* Perth, Western Australia: Dept of Shipping and Transport; 1972:277–286.

45. Polus A, Katz A. An analysis of nighttime pedestrian accidents at specially illuminated crosswalks. *Accid Anal Prev.* 1978;10:223–228.

46. Koepsell T, McCloskey L, Wolf M, et al. Crosswalk markings and the risk of pedestrian-motor vehicle collisions in older pedestrians. *JAMA.* 2002;288: 2136–2143.

47. Agran PF, Winn DG, Anderson CL, Tran C, Del Valle CP. The role of physical and traffic environment in child pedestrian injuries. *Pediatrics.* 1996;98: 1096–1103.

New Roads and Human Health: A Systematic Review

We sought to synthesize evidence of the health effects of construction of new roads by systematically reviewing observational studies of such effects. We included and critically appraised 32 studies.

The review suggested that out-of-town bypasses decrease injuries on main roads through or around towns, although more robust evidence is needed on effects on secondary roads. New major urban roads have statistically insignificant effects on injury incidence. New major roads between towns decrease injuries. Out-of-town bypasses reduce disturbance and community severance in towns but increase them elsewhere. Major urban roads increase disturbance and severance.

More robust research is needed in this area, particularly regarding effects of new roads on respiratory health, mental health, access to health services, and physical activity. (*Am J Public Health.* 2003;93:1463–1471)

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TRANSPORTATION IS AN important determinant of health,[1–3] but the World Health Organization (WHO) has recently expressed concern that the importance of a healthy transportation policy has not been fully recognized. WHO specifically refers to the issue of road travel, stating that "reliance on motorized transport, in particular road transport, continues to increase, resulting in adverse environmental and health effects."[1(p3)] These comments reflect a general emphasis in public health research on negative effects associated with motorized road vehicles.[4–9]

The United States stands out as a nation where the health and well-being of individuals and communities are said to have been adversely affected by dependence on the automobile.[4] Rates of automobile ownership and use in America have long exceeded those found in any other country, while public transport use and walking have been in decline since at least the late 1960s.[10] A range of public health and environmental concerns have been associated with these trends, including smog, urban sprawl, a rising prevalence of obesity, and their associated health problems.[11] Furthermore, between 1970 and 1995, 1.2 million people died on America's roads.[12]

Although rates of automobile ownership are particularly high in the United States,[4] the health concerns associated with motorized road travel are shared by countries across the globe, and the Red Cross has predicted that by 2020 injuries related to traffic will be the world's third largest cause of death and disability.[13] Road construction and automobile dependency have also been associated with community severance (i.e., reduced access to local amenities and disruption of social networks caused by a physical barrier running through the community), increased "disturbance" among residents (e.g., noise, vibration, fumes), and social inequalities.[8,14–17]

In such circumstances, it is little wonder that the building of new roads is often contentious. Yet roads fulfill a fundamental role within local and national infrastructures, and the motorized vehicles that use them can confer benefits in terms of mobility and convenience on substantial sections of a population.[18] In his well-known study of residential streets in San Francisco, Donald Appleyard summed up the paradox implicit in the relationship

between roads and the people who are affected by them: "the street has always been the scene of . . . conflict, between living and access, between resident and traveler, between street life and the threat of death."[14(p1)]

The building of new roads is therefore a public health issue, but the evidence base relating to the health impacts of new roads is disparate and incomplete.[19] In an attempt to provide a better understanding of the positive and negative effects that new roads exert on human health and well-being, we conducted a systematic review of the relevant literature pertaining to developed countries. Our goal was to identify, assess, and synthesize primary studies that focused on new roads and included measurements of effects on human health and well-being.

METHODS

Inclusion and Exclusion

Along with the building of roads where none existed before, the definition of "new road" used in our review included new road bridges and new road tunnels, conversion of gravel tracks into hard-surface roads, and addition of lanes to existing roads (either through road widening or through converting hard shoulders into new lanes).[20] We defined human health impacts as including not only specific health problems but also the concept of general well-being.[21] Illness and injuries were included, as were psychosocial effects such as community severance and disturbance.

We did not include in the review health impacts resulting from the road construction process. Moreover, we excluded studies focusing on general economic and environmental effects resulting from construction of new roads if they did not measure human health as well.

We aimed to include studies conducted in any language, and we sought to include a range of study designs: randomized controlled trials (should any exist), before-and-after studies involving controls, before-and-after studies not involving controls, and retrospective studies involving controls (including historical controls). We also included qualitative studies of health effects.

Search Strategy

The following databases and electronic journal collections were searched from the earliest possible start date up to 2002: ABI Inform, Acompline/Urbaline, Applied Social Sciences Index and Abstracts, BOPCAS, British Humanities Index, Business Source Premier, Campbell Collaboration, Caredata Web, Catchword, Childdata, CINAHL, Cochrane Library, Dissertation Abstracts, Econlit, EI Compendex, Electronic Collections Online, EMBASE, GEOBASE, HMIC/HELMIS, International Bibliography of the Social Sciences, Index to Theses, ingenta/uncover, INSPEC, International Civil Engineering Abstracts, MEDLINE, PAIS, PLANEX, ProceedingsFirst, PsycINFO, Regard, Road Construction Network, SIGLE, Social Science Citation Index, Social Services Abstracts, Sociological Abstracts, TRANSPORT, and ZETOC. The British Library catalogue and the COPAC catalogue were also checked, and Internet sources were searched.

Bibliographies and key journals were hand searched, and experts were contacted. We initially screened 23 259 titles and abstracts, and we retrieved 692 studies for more detailed analysis. Each study involving construction of a new road was independently assessed by 3 reviewers in terms of relevance and methodological rigor.

Critical Appraisal and Data Extraction

We adapted critical appraisal tools from those recommended within the systematic review[22–33] and transport[34–38] methodological literature. Each study was assessed in regard to 9 subject-specific criteria (Tables 1 and 2). These assessments were used as a guide to the methodological soundness of each study, although, as is the case with all critical appraisal tools, they relied on authors accurately describing their methods.

Some results from resident surveys were based on population proportions, while others were based on 5-point, 7-point, or 36-point scales. We recalculated these results as percentages for ease of comparison. We included confidence intervals (CIs), *P* values, and effect size ranges when they were reported in the original article or calculated these statistics if sufficient information was available.

RESULTS

Thirty-two different studies[39–72] were identified, the earliest from 1962 (A.H. Amundsen and R. Elvik, unpublished data, 2001; M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002). Note that some studies appeared in more than one publication, while other publications included multiple studies. Eight studies were identified from electronic databases. One was identified from Web browsing, 4 were identified from personal communications, and 19 were identified from citation follow-ups.

Most of the studies examined either disturbance among local residents or road injuries. No studies were identified that examined the impact of new roads on access to health care, health inequalities, or physical activity. There was sparse evidence on outcomes involving specific physical or mental illnesses. The one exception was an unpublished article that examined respiratory symptoms and respiratory function after the opening of a new road (M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002).

Road Injuries

Table 1 summarizes the results of studies assessing effects of new roads on injury prevalence rates. Seven of the injury studies involved meta-analyses of data from more than one new road site (A.H. Amundsen and R. Elvik, unpublished data, 2001).[41–43,45–47] The other 4 studies in this category examined the impact of a single new road on injuries.[39,40,44,48] The studies covered 3 broad categories of roads: major urban roads (4 studies), out-of-town bypasses (5 studies), and major connecting roads between towns (3 studies). One study included both bypasses and major connecting roads.[45] All involved the use of before-and-after comparisons of police injury statistics adjusted for general trends.

Major urban roads take traffic through urban areas. Out-of-town bypasses are designed to take traffic away from urban areas. Major connecting roads usually join 2 urban areas, relieving

TABLE 1—Summary of Studies Showing Effects of New Roads on Injuries

Study Details	Methods[a]	Effect on Injury Accidents and Casualties (Adjusted for General Trends)
Major urban roads		
Amundsen and Elvik (unpublished data, 2001): Norway, 4 roads	1 2 3 5 6 7 9	19% decrease in injury accidents, including secondary roads
	1 2 3 4 5 6 7	4% decrease in injury accidents, main roads only
Jadaan and Nicholson[39]: New Zealand, 1 road	1 2 3 5 7 8 9	4% decrease in injury accidents
		1% decrease in no. of casualties per injury accident
Sæverås[40]: Norway, 1 road	1 2 3 4 5 9	26% decrease in injury accidents (note: this figure has since been recalculated to 8.5%)[35]
Levine et al.[41]: US, 2 roads	1 2 3 4 6 9	1% decrease in injury accidents
Bypasses		
Andersson et al.[42]: Denmark, 11 roads	1 2 3 5 6 8 9	4% decrease in injury accidents
		6% increase in casualties
Elvik et al.[43]: Norway, 20 roads	1 2 3 4 5 6 7	19% decrease in injury accidents
Jørgensen[44]: Denmark, 1 road	1 2 3 5 8 9	No change in rate of injury accidents (regional trends)
		3% decrease in casualties (regional trends)
Leeming[45]: UK, 19 roads	1 2 3 5 6 7	33% decrease in injury accidents
Newland and Newby[46]: UK, 7 roads	1 2 3 6 7	25% decrease in injury accidents
Major connecting roads		
Jensen[47]: Denmark, 2 roads	1 2 3 5 6 9	25% decrease in injury accidents
Leeming[45]: UK, 5 highways, 39 dual carriageways, 37 lane additions to 2-lane roads	1 2 3 5 6 7	19% decrease in injury accidents: highways
		32% decrease in injury accidents: dual carriageways
		22% decrease in injury accidents: lane additions to 2-lane roads
Newby and Johnson[48]: UK, 1 road	1 2 3 7 8 9	6% decrease in casualties

[a]1 = control for general trends; 2 = reliable/representative sample of data; 3 = sufficient data presented to validate results; 4 = control for regression to the mean; 5 = assessment at least 3 years before and 3 years after; 6 = compares more than one new road; 7 = injury severity considered; 8 = no. of individual casualties included; 9 = accident migration across wider road network considered.

TABLE 2—Summary of Studies Showing Effects of Major Urban Roads on Disturbance Among Local Residents

Study Details (No. of Roads, Before/After Sample, Follow-Up From Date Road Opened)	Methods[a]	Change in Disturbance, %	Reported Effect Range, % (per Road)
Hawley[49]: Australia, 1 road, n = 308/367, 2–3 years	1 3 4 6 7 9	Noise: +3	. . .
Griffiths and Raw[50]: UK, 1 road, n = 42/not reported, 2–3 months	1 2 3 4 7 9	Noise: +24	. . .
Lee et al.[51-53]: UK, 5 roads, n = 960, 5, 10, 30 years	1 3 5 6 7 8	Severance: +14 (mean % trips across road)	5 years: +15 10 years: +13 30 years: +14
Lawson and Walters[54]: UK, 1 road, n = 189/174, 11 months	1 4 6 9	Noise: "significant" increase (no figures presented)	. . .

[a]1 = appropriate sampling; 2 = response rate/follow-up > 60%; 3 = controls/adjustment for confounders; 4 = appropriate exposure measures; 5 = adaptation to disturbance considered; 6 = impact on secondary roads considered; 7 = sufficient data presented to validate results; 8 = compared more than one new road; 9 = prospective study.

older connecting road networks that run through largely rural areas. They are not primarily designed to relieve traffic in urban areas.[45] In instances in which study information was unclear, authors were contacted to clarify details of the roads examined.

Major urban roads. All 4 of these studies considered the effects of new roads on the wider local network. The results were variable. Two studies revealed negligible decreases in the incidence of accidents involving injuries (4% and 1%, respectively).[39,41] Two others revealed statistically significant decreases (19% and 26%) (A.H. Amundsen and R. Elvik, unpublished data, 2001),[40] although reexamination of data from the second study suggests that an estimated decrease in incidence of 8.5% is more accurate than the figure of 26% provided.[35]

One study examined 4 new major urban roads in Oslo and estimated a mean decrease in injury accidents of 4% when only major roads were considered and a decrease of 19% when secondary roads were included (A.H. Amundsen and R. Elvik, unpublished data, 2001). The authors noted that there were systematic variations in the results of the 4 projects. Three of the roads were new tunnels that together were associated with an estimated increase in injury accidents of 10% (95% CI=−8%, 32%) on major roads. The fourth site consisted of road-widening and intersection improvements to an existing road; in this case, injury accidents decreased by an estimated 51% (95% CI=27%, 68%).

Bypasses. The 5 bypass studies showed a general decline in the incidence of injury accidents after the opening of new bypasses. This decline was statistically significant in 2 studies, both of which were published in the 1960s.[45,46] In a recent meta-analysis of 20 bypasses in Norway, the observed decrease in injury accidents of 19% was statistically significant when a fixed effects model was used in the analysis (95% CI=5%, 30%) but was narrowly rejected by significance testing when a random effects model was used

(95% CI=−35%, 0.4%).[43] All of the studies in this category compared the incidence of injury accidents on main through roads in the "before" period with the incidence of injury accidents on both old through roads and new bypasses in the "after" period.

In addition to examining old through roads and new bypasses, 2 studies also included adjacent (secondary) roads in their analyses of injury accidents.[42,44] Each study detected small, statistically insignificant decreases. Andersson et al. found a mean increase in the incidence of injury accidents of 41% along secondary roads that linked new out-of-town bypasses to old main roads that ran through towns.[42] However, this figure included accidents that took place on intersections between the bypasses and the old through roads. Injuries on the old through roads and the new bypasses (but excluding the intersections, where one would expect a large proportion of the accidents to occur) decreased by a mean of 20%.[42]

Major connecting roads. Two of the 3 studies in this category revealed statistically significant reductions in rates of injury accidents. In a study focusing on the construction of 2 highways, Jensen estimated that these roads reduced injury accidents by a mean of 25% (taking secondary roads into account).[47] Leeming estimated that new highways and new dual carriageways reduced injury accidents by 19% and 32%, respectively (on major roads only).[45]

Newby and Johnson presented data on casualty rates but not data on injury accidents[48]; they found that casualty incidence rates fell by 6% after the opening of a new highway (no confidence intervals or significance tests were provided). They examined effects on the secondary road network within 30 miles (48 km) of either side of the new road. The size of the area under investigation could explain the relatively small decrease detected; the effects were greatest on roads within 5 miles of the new highway.

Casualties and injury severity. Most injury studies measured the effects of new roads by examining the incidence of accidents involving injury, but 3 studies also examined numbers of individuals listed as casualties of road accidents.[39,42,44] There was no consistent evidence of a significant difference between the 2 types of measurement in assessing the impact of new roads. The initial results of one study did show a significant increase in casualties but not in injury accidents.[42] However, the authors concluded that this finding was biased by their inclusion of an atypical site in their meta-analysis.

There was little consistent evidence of significant changes in accident severity, possibly because severe and fatal accidents occur relatively infrequently. Leeming found that new connecting roads were associated with a significant decrease in fatal and serious injury accidents (28%; $P<.05$) but not a significant decrease in fatal accidents alone (7%; $P>.05$). Conversely, adding a single overtaking lane to a 2-lane road significantly reduced the rate of fatal accidents (48% decrease; $P<.05$) but not the rate of fatal and serious accidents combined (10% decrease; $P>.05$).[45]

Jadaan and Nicholson provided unadjusted data on injury severity in a study of a new major urban road. There was a marked difference between the road's effect on minor injury accidents (10% increase) and the effect on fatal and serious injury accidents (48% decrease).[39] Amundsen and Elvik's study of new major urban roads showed a 23% decrease in serious and fatal accidents (A.H. Amundsen and R. Elvik, unpublished data, 2001).

Leeming estimated that construction of bypasses led to statistically insignificant ($P>.05$) decreases in serious/fatal injuries combined (12%) and fatal injuries alone (6%).[45] Andersson et al. did not conduct a direct analysis of data on injury severity but inferred an increase in severity from the increase in the mean number of casualties per injury accident.[42]

Disturbance

Twenty-one studies[49–72] involved the use of structured and semistructured surveys to consider the impact of new roads on disturbance (M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002). They focused on major urban roads and bypasses. Types of disturbance included noise, vibration, fumes, and dirt. Some of the studies also considered community severance.

Eleven of the studies were prospective.[49,50,54–64,66] Another 3 compared disturbance levels before and after road construction by means of retrospective questionnaires.[65,67,68] One postconstruction survey estimated preconstruction conditions by comparing intervention areas with control areas that contained no roads of the type under examination.[51–53] An additional 5 studies made no attempt to estimate preconstruction disturbance levels, focusing exclusively on the issue of adaptation to new roads after they had opened.[55,69–72] One postconstruction study examined respiratory symptoms and functioning (M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002). In most of the studies, before-and-after comparisons were not subjected to significance testing. Studies that compared more than one site often presented data on effect size ranges for each new road. We have included these data in our tables in instances in which they were available.

Major urban roads. There were 4 studies of new major urban roads (Table 2). Three examined disturbance from traffic noise, all of which reported increases.[49,50,54] One reported a minor increase of 3% from a prospective survey involving a new road in a residential area.[49] This road was intended to relieve congestion from another urban road. A survey of residents living near the relieved route showed a 20% decrease in the prevalence of respondents reporting disturbance. The other 2 noise studies surveyed only residents living near the new road.[50,54] Both reported a mean increase in resident disturbance, although one did not provide data.[54]

One study investigated the issue of community severance.[51–53] Neighborhood traversal was found to be an average of 14% lower in areas surrounding new roads. However, residents living in these areas partially adapted to the barrier effect produced by the major roads by expanding the boundaries of what they considered to be their neighborhood to include amenities situated further away from their homes but on their own side of the road.

TABLE 3—Summary of Studies Showing Effects of New Bypasses on Disturbance Among Residents of the Area Being Bypassed

Study Details (No. of Roads, Before/After Sample, Follow-Up From Date Road Opened)	Methods[a]	Change in Disturbance, %	Reported Effect Range, % (per Road)
Griffiths and Raw[50,55]: UK, 5 roads, n = 469/391, 3 months, 22 months	1 2 3 4 5 7 8 9	Noise, 2–3 months: –35	–60, –28
		Noise, 17–22 months: –32	. . .
Prescott-Clarke[56]: UK, 2 roads, n = 562/552, 1 year	1 2 3 4 6 8 9	Noise: –6	–8, –3
		Vibration: –5	–6, –3
		Fumes: –3	–3, –2
		Dirt: –5	–8, –2
Baughan and Huddart[57]: UK, 9 roads, n = 407/338, 1–2 months	1 2 3 4 8 9	Noise: –39	–51, –22
Morrissey and Hedges[58]: UK, 2 roads, n = 208/120, 14 months	1 4 5 7 8 9	Noise: –40	–43, –36
		Vibration: –27	–30, –24
		Fumes: –23	–24, –21
		Dirt: –36	–38, –33
		Severance: –17	–23, –11
Fullerton et al.[59]: UK, 2 roads, n ≈ 430/505, follow-up length not reported	2 4 6 7 8 9	Noise: –41	–51, –30
		Vibration: –16	–13, –19
		Fumes: –17	–17, –16
		Dirt: –13	–13, –12
		Severance: –8	. . .
Mackie et al.[60–62]: UK, 2 roads, n = 205/198, 3–6 months	1 4 6 7 8 9	Noise: –31	–46, –15
		Vibration: –44	–69, –19
		Fumes: –23	–41, –5
		Dirt: –41	–70, –11
		Sleep disturbance: –21	. . .
Brown et al.[63]: Australia, 1 road, n = 49/92, 15–21 months	2 3 4 6 9	Noise: –45	. . .
Dawson[64]: UK, 1 road, n = 142/136, 1 year	1 4 6 7 9	Sleep disturbance	. . .
		Main road: –4	
		Secondary roads: +1	
Nilsson[65]: Sweden, 9 roads, n = 3327, follow-up length not reported	2 3 6 8	Noise: –4	. . .
		Vibration: –3	
		Fumes: –4	
		Severance: –8	
Haakenaasen[66]: Norway, 1 road, n = 64/68, 1 year	1 7 8 9	Noise: 0	. . .
		Noise, night only: –33	
Mehra and Lutz[67]: Germany, 1 road, n = 82, follow-up length not reported	1 4 6	Noise: –7	–35, +28
Mudge and Chinn[68]: UK, 1 road, n = 237, 7 years (results give details of indoor/outdoor disturbance)	6 7	Noise: –34/–41	. . .
		Vibration: –38/–45	
		Fumes: –45/–45	
		Dirt: –43/–48	
		Severance: . . ./–50	

[a]1 = appropriate sampling; 2 = response rate/follow-up > 60%; 3 = controls/adjustment for confounders; 4 = appropriate exposure measures; 5 = adaptation to disturbance considered; 6 = impact on secondary roads considered; 7 = sufficient data presented to validate results; 8 = compared more than one new road; 9 = prospective study.

Bypasses. The 12 bypass studies (Table 3) revealed a general decrease in disturbance among residents of towns being bypassed.[50,55–68] This decrease generally occurred on the towns' secondary roads as well as main roads. Small towns tended to experience the largest decreases in through traffic as a result of new bypasses, and consequently they experienced greater benefits in terms of reduced disturbance.[50,55,60–62]

One important source of bias in many of these studies was a failure to consider disturbance among rural residents living near the bypass. However, 3 studies did present numerical data on this issue.[56,64,67] Prescott-Clarke stated that the bypass examined increased the percentages of rural residents disturbed by noise, both when they were indoors (11% increase) and when they were outdoors (15% increase).[56] Dawson stated that the proportion of rural residents reporting sleep disturbances increased by 22%.[64] Mehra and Lutz reported a mean increase in noise disturbance of 79% among residents living in areas where traffic noise increased after the opening of a bypass.[67]

Adaptation and respiratory health. Three quantitative studies investigated adaptation to disturbance after the opening of major urban roads (Table 4).[69–71] They showed no evidence of adaptation. The one qualitative study conducted was perhaps more sensitive to adaptation than the quantitative surveys. This qualitative study reported that adaptation occurred in the following domains: attitude (e.g., reconciling oneself to the inevitability or usefulness of the new road), behavior (e.g., spending less time

TABLE 4—Summary of Studies on Disturbance After the Opening of New Roads: Postconstruction Only

Study Details (No. of Roads, Samples, Length of Follow-Up From Road Opening)	Methods[a]	Outcome, %	Reported Effect Range, % (per Road)
Major urban roads			
Jonnson and Sörensen[69]: Sweden, 1 road, n = 84/60, 18 months	1 2 3 4 5 7	Noise: +12	. . .
		Sleep disturbance: +46	
		Tiredness, headache, nerves: +17	
Morrissey and Hedges[70]: UK, 2 roads, n = 219/142, 15 months	1 4 5 7 8	Noise: +3	0, +5
		Vibration: +8	+2, +13
		Fumes: +3	+2, +3
		Dirt: +8	+7, +9
		Severance: +3	+1, +5
		Sleep disturbance: 0	–1, +1
Weinstein[71]: US, 1 road, not reported/n = 160, 16 months	1 3 4 5 7	Noise	. . .
		Cohort study: +5	
		Repeat cross-sectional study: –4	
Bypasses			
Griffiths and Raw[55]: UK, 5 roads, n = 414/430, 7 years	1 2 3 4 5 7 8	Noise: +6	Range: -9, +15
Qualitative			
Hedges[72]: UK, 4 major urban roads, 1 bypass, interviews (n = 24) and focus groups (n = 60), 5 years	Appropriate sampling Use of interviews and focus groups Sufficient use of quotes to validate conclusions Multisite comparison	Major urban roads increase all types of disturbance and severance; residents adapt their behavior and attitudes and make changes to home environment to mitigate effects of new road Bypass decreases all types of disturbance and severance; no strong evidence of residents being less appreciative of the benefits over time (i.e., no evidence of adaptation)	

[a]1 = appropriate sampling; 2 = response rate/follow-up > 60%; 3 = controls/adjustment for confounders; 4 = appropriate exposure measures; 5 = adaptation to disturbance considered; 6 = impact on secondary roads considered; 7 = sufficient data presented to validate results; 8 = compared more than one new road; 9 = prospective study.

in certain rooms of one's house), and environment (e.g., installing fences).[72] Quantitative and qualitative studies of bypasses did not provide any consistent evidence of adaptation to decreased disturbance.[55,72]

A draft article by Burr et al. was the only study identified in this review to measure specific respiratory health impacts resulting from a new road (M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002). The authors found that, during the first year after a bypass opening, there was little consistent evidence of improvements in respiratory symptoms or decreases in peak expiratory flow variability among town residents attributable to the opening of the bypass. There was a net decrease of 10.3% in the prevalence of rhinitis affecting activities among residents of congested streets in comparison with residents of uncongested streets (95% CI = 3.1%, 17.3%). In addition, there was a significant improvement in peak flow variability among residents of uncongested streets in the morning but not the evening. Interpretation of the results was complicated by an observed trend involving improved lower respiratory function among residents of the bypassed town's uncongested streets, a trend that may have been attributable to the bypass or to confounding factors.

DISCUSSION

Impact of New Roads

The utility and desirability of new roads should be assessed in terms of their impact on the economy, the general environment, and the health and well-being of individuals most immediately affected. This review has synthesized the available evidence base pertaining to only one of these categories: health and well-being. Systematic reviews of the other 2 categories are also required. We plan to conduct such a review of economic effects in the near future.

Overall, there was little evidence that new major urban roads significantly reduce the incidence of injury accidents, except for a study of widening and intersection improvements made to a single urban road in Norway (A.H. Amundsen and R. Elvik, unpublished data, 2001). New major urban roads appear to increase noise disturbance and severance effects in local communities. There is qualitative, but not quantitative, evidence that residents may respond to these effects via behavioral, attitudinal, and environmental adaptation. However, in one study increased disturbance could still be detected 3 years after the opening of a new road,[49] and other studies showed that evidence of severance effects could still be detected 30 years after road openings.[51–53]

The evidence on out-of-town bypasses indicates that they reduce the incidence of injury accidents on main routes through or around towns. Secondary roads within towns may be affected differently (e.g., the Andersson et al. study[42] suggests that bypasses lead to increases in injuries on secondary roads and intersections). Unfortunately, detailed accident statistics are not always available for secondary roads (A.H. Amundsen and R. Elvik, unpublished data, 2001), which perhaps explains the relative lack of robust evidence on how new bypasses affect the distribution of injury accidents across broader road networks.

New bypasses reduce disturbance among residents of bypassed towns, especially small towns, and one study showed a beneficial effect on minor nasal symptoms (M.L. Burr, G. Karani, B. Davies, B.A. Holmes, and K.L. Williams, unpublished data, 2002). Although new bypasses reduce the amount of disturbance in some communities, people living near the bypasses themselves typically experience adverse effects (which were addressed in only a few studies).[56,64,67] Similarly, there is evidence that major new roads connecting urban centers are associated with significant decreases in accident injuries, but there is no evidence regarding the effects on rural residents.

Research Implications

The present review has collated the available evidence on the impact of new roads on human health and well-being. Our search was to some extent hampered by poorly indexed transport databases, reinforcing the claims made by Wentz et al.[19] regarding the need to improve the electronic referencing of transport studies. Despite an extensive literature search, most of the studies included in this review were not found in electronic databases. This suggests that systematic reviews of nonclinical topics, particularly in the area of transportation, may need to rely more on citation searching, hand searching, bibliographies, and contacts with experts than on searches of electronic databases.

The quality of the studies identified was generally low, although some of the problems arose from methodological difficulties inherent in conducting quasi-experimental assessments of environmental modifications. Frequently occurring potential sources of bias included nonrandomized sampling, low response and follow-up rates, overreliance on inadequately tested self-assessment questionnaires, lack of controls, and lack of long-term longitudinal studies. Disturbance studies were generally subject to more methodological problems than injury studies. Although we were able to identify directions of effects in the disturbance studies reviewed, heterogeneity in the measurement of outcomes prevented us from comparing specific effect sizes between studies.

One would normally expect to see an inverse relationship between methodological robustness and effect size, but the present review provides little consistent evidence of this so-called "iron law" of evaluation.[73] Bypass injury studies represented an exception: those that included observations of secondary roads registered smaller effects than those that did not.

This review has identified a bias in favor of measuring effects among urban as opposed to rural communities. Future research should aim to redress this situation and fill evidence gaps surrounding the impacts of new roads on access to health services, physical activity, health inequalities, and the health effects of specific pollutants. More rigorously designed prospective studies should also be carried out to assess the size and distribution of wider health impacts of new road schemes. Disturbance studies show that residents benefit from reduced traffic volumes. Alternative interventions designed to reduce traffic in residential areas should also be evaluated so that their costs and benefits can be compared with those of new road programs.

Summary

The results of this review will be of value to public health professionals and others seeking to estimate the potential health and social effects of new road building. Our findings will also contribute to the wider debate on the social determinants of health, among which transport and related policies are currently seen as playing a major role. Our overall results suggest that, contrary to the sometimes expressed view that new road construction has only negative effects, new roads have a range of positive and negative effects on health that vary according to type of road and population under consideration. ■

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Contributors

M. Egan planned the study; collected, analyzed, and synthesized the data; and wrote the article. M. Petticrew supervised study planning, assisted in data analysis and synthesis, and contributed to the writing of the article. D. Ogilvie assisted in data analysis and synthesis and contributed to the writing of the article. V. Hamilton assisted in data collection and analysis and contributed to the writing of the article.

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References

1. *Charter on Transport, Environment and Health.* Copenhagen, Denmark: World Health Organization; 1999.

2. Macintyre S, Ellaway A. Ecological approaches: rediscovering the role of the physical and social environment. In: Berkman L, Kawachi I, eds. *Social Epidemiology.* Oxford, England: Oxford University Press Inc; 2000: 332–348.

3. Dora C. A different route to health: implications of transport policies. *BMJ.* 1999;318:1686–1689.

4. Pucher J, Lefèvre C. *The Urban Transport Crisis in Europe and North America.* London, England: Macmillan; 1996.

5. Maddison D, Pearce D, Johansson O, Calthrop E, Litman T, Verhoef E. *The True Costs of Road Transport.* London, England: Earthscan; 1996.

6. Hillman M. Healthy transport policy. In: Draper P, ed. *Health Through Public Policy: The Greening of Public Health.* London, England: Green Print; 1991:82–91.

7. Fletcher T, McMichael A, eds. *Health at the Crossroads: Transport Policy and Urban Health.* West Sussex, England: John Wiley & Sons Inc; 1997.

8. McCarthy M. Transport and health. In: *Social Determinants of Health.* Oxford, England: Oxford University Press Inc; 1999:132–154.

9. Künzli N, Kaiser R, Medina S, et al. Public-health impact of outdoor and

traffic-related air pollution: a European assessment. *Lancet.* 2000;356: 795–801.

10. Federal Highway Administration. *Nationwide Personal Transportation Survey.* Washington, DC: US Dept of Transportation; 1993.

11. McCann B, DeLille B. *Mean Streets 2000: Pedestrian Safety, Health and Federal Transport Spending.* Washington, DC: Surface Transportation Policy Project; 2000.

12. Pucher J. Transportation paradise: realm of the nearly perfect automobile? *Transportation Q.* 1999;53(3):115–120.

13. *World Disasters Report.* Geneva, Switzerland: International Federation of Red Cross and Red Crescent Societies; 1998.

14. Appleyard D, Gerson MS, Lintell M. *Livable Streets.* Berkeley, Calif: University of California Press; 1981.

15. Davis A. Liveable streets through environmental capacity limits. In: *PTRC European Transport, Highways and Planning 20th Summer Annual Meeting Proceedings: Seminar B, Environmental Issues.* Vol. 14. London, England: PTRC Education and Research Services; 1992:103–126.

16. Bosselmann P, Macdonald E, Kronemeyer T. Livable streets revisited. *J Am Plann Assoc.* 1999;65:168–180.

17. Lucas K, Grosvenor T, Simpson R. *Transport, the Environment and Social Exclusion.* York, England: Joseph Rowntree Foundation; 2001.

18. Dunn J. *Driving Forces: The Automobile, Its Enemies, and the Politics of Mobility.* Washington, DC: Brookings Institution Press; 1998.

19. Wentz R, Roberts I, Bunn F, Edwards P, Kwan I, Lefebvre C. Identifying controlled evaluation studies of road safety interventions: searching for needles in a haystack. *J Safety Res.* 2001; 32:267–276.

20. Urban Motorways Committee. *New Roads in Towns.* London, England: Her Majesty's Stationery Office; 1972.

21. Evans R, Stoddart G. Producing health, consuming health care. *Soc Sci Med.* 1990;31:1347–1363.

22. Clarke M, Oxman AD, eds. *Cochrane Reviewers Handbook 4.1.5.* Oxford, England: Update Software; 2002.

23. National Health Service, Centre for Reviews and Dissemination. *Undertaking Systematic Reviews of Research on Effectiveness: CRD's Guidance for Those Carrying Out or Commissioning Reviews.* York, England: University of York; 2001. Report 4.

24. Cooper H, Hedges LV, eds. *Handbook of Research Synthesis.* New York, NY: Russell Sage Foundation; 1994.

25. Greenhalgh T. How to read a paper: papers that summarise other papers (systematic reviews and meta-analyses). *BMJ.* 1997;315:1672–1675.

26. Schulz K, Chalmers I, Hayes R, Altman D. Empirical evidence of bias: dimensions of methodological quality associated with estimates of treatment effects in controlled trials. *JAMA.* 1995; 273:408–412.

27. Heacock H, Koehoorn M, Tan J. Applying epidemiological principles to ergonomics: a checklist for incorporating sound design and interpretation of studies. *Appl Ergonomics.* 1997;28: 165–172.

28. Hyman R. How to critique a published article. *Psychol Bull.* 1995;118: 178–182.

29. Verhagen A, de Vet H, de Bie R, Boers M, van den Brandt P. The art of quality assessment of RCTs included in systematic reviews. *J Clin Epidemiol.* 2001;54:651–654.

30. Fowkes F, Fulton P. Critical appraisal of published research: introductory guidelines. *BMJ.* 1991;302: 1136–1140.

31. Downs S, Black N. The feasibility of creating a checklist for the assessment of the methodological quality both of randomised and non-randomised studies of health care interventions. *J Epidemiol Community Health.* 1998;52: 377–384.

32. DuRant R. Checklist for the evaluation of research articles. *J Adolesc Health.* 1994;15:4–8.

33. Vickers A. Critical appraisal: how to read a clinical research paper. *Complementary Ther Med.* 1995;3:158–166.

34. Hauer E. *Observational Before-After Studies in Road Safety: Estimating the Effect of Highway and Traffic Engineering Measures on Road Safety.* Oxford, England: Pergamon Press; 1997.

35. Elvik R. The importance of confounding in observational before-and-after studies of road safety measures. In: *Proceedings of the 13th International Cooperation on Theories and Concepts in Traffic Safety Workshop.* Corfu, Greece: International Cooperation on Theories and Concepts in Traffic Safety; 2000: 105–117.

36. Elvik R. Evaluations of road accident blackspot treatment: a case of the iron law of evaluation studies? *Accid Anal Prev.* 1997;29:191–199.

37. Elvik R. Some difficulties in defining populations of entities for estimating the expected number of accidents. *Accid Anal Prev.* 1988;20:261–275.

38. Hedges A, Morrissey C. *Study of Adaptation to Traffic Nuisance: A Comparison of Research Methods.* London, England: Social and Community Planning Research Publications; 1986.

39. Jadaan KS, Nicholson AJ. Effect of a new urban arterial on road safety. *Aust Road Res.* 1988;18:213–223.

40. Sæverås OJ. *Vestre innfartsåre: sammenligning av ulykkessituasjonen før og etter åpning av ny innfartsåre fra vest (ytre del).* Bergen, Norway: Statens Vegvesen Hordaland, Trafikksikkerhetsseksjonen; 1998.

41. Levine DW, Golob TF, Recker WW. Accident migration associated with lane-addition projects on urban freeways. *Traffic Eng Control.* 1988;29: 624–629.

42. Andersson PK, Lund BLC, Greibe P. *Omfartsveje: den trafiksikkerhedsmæssige effekt.* Copenhagen, Denmark: Danmarks TransportForskning; 2002.

43. Elvik R, Amundsen FH, Hofset F. Road safety effects of bypasses. *Transportation Res Rec.* 2001;1758:13–20.

44. Jørgensen NO. The safety effects of a major infrastructure project. In: *Euro Traffic '91: Congress Report.* Aalborghallen, Denmark: Pan-European Traffic Congress; 1991:247–255.

45. Leeming JJ. *Road Accidents: Prevent or Punish?* London, England: Cassell; 1969.

46. Newland VJ, Newby RF. Changes in accident frequency after the provision of by-passes. *Traffic Eng Control.* 1962;3:614–616.

47. Jensen HN. *Vedrørende den sikkerhedsmæssige effect af etablering af motorveje.* Copenhagen, Denmark: Sektorplannafdelingen Vejdirektoratet; 1995.

48. Newby RF, Johnson HD. Changes in the numbers of accidents and casualties on main roads near the London-Birmingham motorway. *Proc Aust Road Res Board.* 1964;2:558–564.

49. Hawley L. F3 freeway—Wahroonga to Berowra: lessons learnt about the relationship between measured noise and community annoyance. In: *Proceedings of the Australian Road Research Board 17th Conference: Part 7, Environment and Planning.* Vermont South, Victoria, Australia: Australian Road Research Board; 1994:225–246.

50. Griffiths ID, Raw GJ. Community and individual response to changes in traffic noise exposure. *J Sound Vibration.* 1986;111:209–217.

51. Lee T, Tagg S. The social severance effects of major urban roads. In: Stringer P, Wenzel H, eds. *Transportation Planning for a Better Environment.* New York, NY: Plenum Press; 1976: 267–281.

52. Lee TR, Tagg SK, Abbott DJ. Social severance by urban roads and motorways. In: *Symposium on Environmental Evaluation, Canterbury, 25–27 Sept 1975.* London, England: Her Majesty's Stationery Office; 1976: 72–86.

53. Lassière A. Severance. In: Lassière A, ed. *The Environmental Evaluation of Transport Plans.* London, England: Dept of the Environment; 1976:110–155.

54. Lawson BR, Walters D. The effects of a new motorway on an established residential area. In: Canter D, Lee T, eds. *Psychology and the Built Environment.* London, England: Architectural Press; 1974:132–138.

55. Griffiths ID, Raw GJ. Adaptation to changes in traffic noise exposure. *J Sound Vibration.* 1989;132:331–336.

56. Prescott-Clarke P. *People and Roads in the Lake District: A Study of the A66 Road Improvement Scheme.* Crowthorne, England: Transport and Road Research Laboratory; 1980. TRRL supplementary report 606.

57. Baughan CJ, Huddart L. Effects of changes in exposure to traffic noise. In: *PTRC European Transport, Highways and Planning 20th Summer Annual Meeting Proceedings: Seminar B, Environmental Issues.* Vol. 14. London, England: PTRC Education and Research Services; 1992:115–126.

58. Morrissey C, Hedges B. *Adaptation to Decreases in Traffic Exposure.* Crowthorne, England: Transport and Road Research Laboratory; 1991. TRRL report 246.

59. Fullerton J, Goodwyn E, McQueen B. *Measuring the Performance of Roads: A Study of the Stonehaven and Gatehouse-of-Fleet Bypasses.* Edinburgh, Scotland: Scottish Development Dept, Central Research Unit; 1987.

60. Mackie AM, Griffin LJ. *Before and After Study of the Environmental Effects of the Tring By-Pass.* Crowthorne, England: Transport and Road Research Laboratory; 1977. TRRL report LR 746.

61. Mackie AM, Griffin LJ. *Environmental Effects of By-Passing Small Towns: Case Studies at Boughton, Dunkirk and Bridge.* Crowthorne, England: Transport and Road Research Laboratory; 1978. TRRL report SR 349.

62. Mackie AM, Davies CH. *Environmental Effects of Traffic Changes.* Crowthorne, Berks: Transport and Road Research Laboratory; 1981. TRRL report LR 1015.

63. Brown AL, Hall A, Kyle-Little J. Response to a reduction in traffic noise exposure. *J Sound Vibration.* 1985;98: 235–246.

64. Dawson RFF. *Environmental Effects of the Alton By-Pass.* Crowthorne, England: Transport and Road Research Laboratory; 1973. TRRL report LR 589.

65. Nilsson G. *Förbifarter del 2: enkätundersökning till boende och kvalitativa effekter av förbifartslösningar.* Linköping, Sweden: Väg-och transportforskningsinstitutet; 1994.

66. Haakenaasen B. *Virkninger av trafikksløsninger: korttidsvirkninger av omkjøringsvegen på Gol.* Oslo, Norway: Transportøkonomisk Institutt; 1980.

67. Mehra SR, Lutz C. Berechnung und subjektive Wahrnehmung der Lärmpegeländerung aufgrund einer neu erstellten Umgehungsstraße: Korrelation zwischen Mess- und Befragungsergebenissen. *Z Lärmbekämpfung.* 2000;47(2): 58–67.

68. Mudge G, Chinn L. *The Impact of the Okehampton Bypass.* Crowthorne, England: Transport and Road Research Laborartory; 1997. TRL report 268.

69. Jonsson E, Sörensen S. Adaptation to community noise: a case study. *J Sound Vibration.* 1973;26:571–575.

70. Morrissey C, Hedges B. *Adaptation to Increases in Traffic Exposure.* Crowthorne, England: Transport and Road Research Laboratory; 1991. TRRL report 245.

71. Weinstein ND. Community noise problems: evidence against adaptation. *J Environ Psychol.* 1982;2:87–97.

72. Hedges B. *Adaptations to Traffic Noise.* London, England: Social and Community Planning Research; 1983.

73. Rossi PH, Freeman HE. *Evaluation: A Systematic Approach.* 3rd ed. Beverley Hills, Calif: Sage Publications; 1985.

Healthy Housing: A Structured Review of Published Evaluations of US Interventions to Improve Health by Modifying Housing in the United States, 1990–2001

We sought to characterize and to evaluate the success of current public health interventions related to housing.

Two reviewers content-analyzed 72 articles selected from 12 electronic databases of US interventions from 1990 to 2001. Ninety-two percent of the interventions addressed a single condition, most often lead poisoning, injury, or asthma. Fifty-seven percent targeted children, and 13% targeted seniors. The most common intervention strategies employed a one-time treatment to improve the environment; to change behavior, attitudes, or knowledge; or both. Most studies reported statistically significant improvements, but few (14%) were judged extremely successful.

Current interventions are limited by narrow definitions of housing and health, by brief time spans, and by limited geographic and social scales. An ecological paradigm is recommended as a guide to more effective approaches. (*Am J Public Health.* 2003; 93:1471–1477)

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PUBLIC HEALTH RESEARCHERS and practitioners have long recognized that housing influences health. Over the last 150 years, housing reformers and public health workers have periodically joined forces to improve health by strengthening housing regulations, advocating for better housing conditions, or reducing hazards such as fire, lead poisoning, injuries, or window falls.[1–4] A substantial body of literature demonstrates that poor housing can contribute to infectious disease transmission, injuries, asthma symptoms, lead poisoning, and mental health problems[4,5–7]—both directly (e.g., because of environmental hazards)[5] and indirectly (e.g., by contributing to psychosocial stress that exacerbates illness).[8]

Renewed interest in housing parallels a growing interest in ecological approaches to the study of complex health problems and an examination of the social determinants of health and the causes of persistent socioeconomic, racial, and ethnic disparities in health.[9,10] Several recent reports have demonstrated the value of considering multilevel (e.g., individual, family, social network, community, state) determinants of a variety of health outcomes.[11–14] Public health advocates have emphasized the importance of creating interventions that address these influences on health[15,16] and of utilizing ecological approaches that seek changes in both the physical and the social environment, at various levels of organization.

Applied to housing, the ecological approach suggests the importance of looking at characteristics of and interactions among residents, housing units, buildings, blocks, and neighborhoods, as well as housing owners, policies, and institutions that provide or regulate housing and health, to understand their contributions to population health. It also suggests that environmental factors interact with psychosocial variables at several levels to produce different patterns of health and disease.[17]

In this report, we assess the extent to which published studies of interventions designed to improve health by modifying housing reflect these new insights. This study differs from another recent review of the effect of improved housing on health[18] in several ways: (1) we focused on a wider range of housing interventions, (2) we used an ecological paradigm that includes behavior at different levels as producers of both housing conditions and health outcomes, and (3) we restricted the database to US studies over 10 years. Our goals were to

1. Describe the objectives, populations, settings, intervention characteristics, and results of these studies
2. Describe and assess the methods used to evaluate these interventions
3. Assess the extent to which intervention studies addressed

multiple levels of causation or multiple outcomes
4. Identify the strengths, limitations, and gaps in the existing literature on housing interventions to improve health
5. Identify directions for future research, policy, and practice

IDENTIFYING HOUSING-BASED HEALTH INTERVENTIONS

To identify relevant studies, a computerized search of 12 bibliographic databases (Cinahl, CSA, EBSCO, ERIC, InfoTrac, MEDLINE, ProQuest, PsycINFO, PubMed, Science Direct, Social Science Abstracts, Sociological Abstracts, and Wiley Intersciences) in the health and social sciences was conducted.

The following key words were used, in various combinations, in the search: *asbestos, asthma, allergens (housing-related), cockroaches, child health, dampness, depression, environmental health, falls, formaldehyde, fungi, health, home, housing, infectious disease, intervention, injuries, lead poisoning, mental health, moisture, mold, morbidity, prevention, rodents, stress,* and *vermin.*

The criteria for inclusion in this study were housing interventions to improve health, conducted in the United States and published in peer-reviewed journals between January 1990 and December 2001. *Housing interventions* were defined as intentional, systematic efforts to improve residential conditions, either directly or indirectly, through 1 or more of the following measures: rehousing (moving to new housing); changes in physical infrastructure; changes in indoor equipment or furniture; changes in participants' knowledge or behavior; changes in community norms or collective behavior; changes in housing policy and regulatory practices; and changes in health practitioners' behavior related to housing effects on health. To be included, studies had to describe both the intervention and the evaluation.

Interventions involving persons diagnosed with conditions that were not directly related to housing—for example, HIV infection, schizophrenia (but not depression)—were excluded. Interventions directed at homeless populations were also excluded because they have been reviewed elsewhere.[19–22]

From the database search, a total of 3204 titles were generated. Of these, 258 were deemed to be potentially eligible, based on the title or abstract. The full articles were then retrieved and carefully reviewed to determine whether they fit the inclusion criteria. The bibliographies of these articles were also searched to identify additional relevant articles. This process yielded a total of 72 housing studies designed to improve health or designed for another purpose but including health as a measurable outcome. Of the 72 studies, 3 interventions were included twice but were related to different outcome measures.

Interventions that met the criteria for inclusion were coded, using an instrument adapted from a similar project.[16] At least 2 of the authors carefully reviewed each of the articles identified by the searches. At least 3 authors discussed and resolved disagreements among the 2 primary reviewers. All coding was based on the authors' account. When the article was not clear about a particular coding category, at least 3 reviewers assigned the categories based on a close reading of the text.

THE NATURE OF HOUSING–HEALTH INTERVENTIONS

The intervention settings and target populations included in these studies are summarized in Table 1. Housing interventions were largely carried out in urban settings: more than half the studies took place in large or medium-sized cites. Only 2 studies were carried out in exclusively rural settings. The majority of projects were conducted in either

TABLE 1—Intervention Settings and Target Populations

Characteristic	No. Studies	% of Studies
Geographic region		
Mid-Atlantic	16	22
Midwest/Great Plains	15	21
New England	13	18
South/Southeast/Southwest	9	13
Pacific Coast	7	10
National or >1 region	6	8
Unspecified/other	6	8
Type of setting		
Large city	31	43
Mid-sized city	9	13
Small town or city	4	6
Rural area	2	3
National or >1 setting	2	3
Unspecified	24	33
Age of target population		
Children	41	57
Adolescents	3	4
Seniors	9	13
Other adults	3	54
Unspecified	16	22
Predominant race/ethnicity of target population[a]		
African American	22	23
Latino	13	14
White, non-Hispanic	15	16
Asian, Pacific Islander	2	2
Other, unspecified	43	45
Gender		
Male	1	1
Female	3	5
Both	68	94
Participants' predominant SES		
Low income	22	31
Middle income	4	6
Multiple/unspecified	46	64

Note. SES = socioeconomic status.
[a]Multiple responses permitted; percentages are reported as percentage of total studies (n = 72).

TABLE 2—Intervention Sponsorship, Staffing, and Funding

Characteristic	No. Studies	% of Studies
Lead and co-sponsors[a]		
University/college	55	76
Medical center	27	38
Health department	15	21
Other (e.g., corporation, housing or other government agency)	46	64
Unspecified	5	7
Funders		
Federal government	34	47
State or local government	8	11
Private	8	11
Public and private	10	14
Unspecified	12	17
Primary funding category		
Health	42	58
Housing	7	10
Environment	4	6
Unspecified	19	25
Project staff[a]		
Health care provider	32	44
Health educator	11	15
Environmental or housing specialist	25	35
Community residents/community health workers	13	18
Unspecified	19	26

[a]Multiple responses permitted; percentages are reported as percentage of total studies (n = 72).

mid-Atlantic (22%); Midwest/Great Plains (21%); or New England (18%) states.

A majority of the studies focused on housing-related issues that can affect children's health (57%). Senior citizens constituted the second largest age category, representing 13% of the studies. Fewer than half of the studies reviewed provided specific information on other key sociodemographic characteristics—such as race/ethnicity and socioeconomic status. When such information was reported, the primary focus was on low-income residents of color.

Sponsorship, staff, and funding characteristics are described in Table 2. Colleges and universities, medical centers, and health departments were the most frequent lead or co-sponsors. Almost three quarters of the studies reported receiving full or partial funding from governmental sources. Among public funders, the federal government predominated (47%) over state or local sources (11%). Funding was more likely to be health-related (58%) than housing-related (10%) or environmentally related (6%). Many interventions were staffed by multidisciplinary teams, comprising health care providers (44%), housing or environmental specialists (35%), health educators (15%), and community residents or community health workers (18%).

Intervention design characteristics are listed in Table 3. All were targeted toward primary or secondary public health prevention, or both. The primary focus was on addressing environmental hazards. Lead paint hazards (36%), safety hazards (35%), and asthma triggers/air quality hazards (29%) were the predominant areas of concern. More than 92% addressed a single housing condition. Eighty-five percent conducted one-time interventions—such as a single training program, a single cleaning, or remediation of hazards at one point in time. Interventions often targeted vulnerable populations. For example, the majority of lead poisoning interventions were targeted toward children younger than 5 years and their parents, whereas the majority of fall and other injury interventions were targeted toward seniors.

The most common intervention strategies involved making environmental improvements (31%), educating participants (32%), or both (35%). Interventions were predominately aimed at dwelling unit or participant-level change, or both. Accordingly, the objectives of most of the interventions to effect individual-level change—either psychosocial change (e.g., participants' knowledge, attitudes, and behavior; 24%); environmental change (physical conditions in individual dwelling units; 22%); or a combination of psychosocial, environmental, and health changes (47%). Only 5 interventions (7%) were aimed at communitywide change, all in combination with individual-level change. Only 15% of the articles reviewed mentioned participant or stakeholder involvement in planning or implementing interventions. In a few instances, researchers employed a participatory approach.[23–25]

Most interventions focused narrowly on a particular health or exposure condition, in part because of the specificity of public policies (as in the case of lead or firearms storage) and funding streams (as indicated in authors' acknowledgments to funders). Many public health interventions focused on specific technologies or diseases. In comparison, rehousing[17,26,27] or home visit interventions[25,28–30] emphasized well-being, broadly defined, suggesting disciplinary and methodological differences in conceptions of how housing affects health. Many authors reported that budgetary and administrative constraints on interventions and analyses also played a part in narrowing the focus of interventions.

EVALUATION CHARACTERISTICS

All interventions reviewed here included an evaluation component. Characteristics of the evaluation are described in Table 4. More than three quarters of the projects were evaluated by persons hired by the agency or organization conducting the intervention. The most common evaluation methods were environmental sampling; surveys and interviews; and physiological measures. More than 80% employed a quantitative evaluation methodology. About half used a randomized design, and about 60% included a comparison group. Eighty-five percent collected information on outcome measures before the intervention *(preintervention measures),* 43% collected information on outcome measures immediately after the interven-

TABLE 3—Intervention Design Characteristics

Characteristic	No. Studies	% of Studies
Prevention level		
Primary prevention	44	61
Secondary prevention	22	31
Both	6	8
Primary intervention focus		
Lead-based paint hazards	25	35
Injury hazards	26	36
Asthma triggers (e.g., vermin, mold) + air quality	21	29
Access to housing	2	3
Number of housing conditions addressed in intervention		
1	59	92
2	5	8
Associated health condition		
Lead poisoning only	25	35
Asthma/respiratory only	15	21
Injury only	20	28
Cancer only	2	3
Multiple health conditions	10	14
Intervention level		
Individual knowledge, attitudes, behavior only	13	18
Dwelling unit only	31	43
Building only	1	1
Community only	4	6
Multiple levels	23	32
Intervention objectives		
Individual level change		
Psychosocial change only (participant knowledge/attitudes/behavior)	17	24
Environmental change only (physical conditions in dwelling unit)	16	22
Psychosocial, environmental/health status change	34	47
Community- and individual-level change	5	7
Quantitative health-related goals		
Yes	49	68
No	23	32
Number of intervention periods		
1	63	88
≥ 2	9	12
Length of intervention		
< 1 year	42	58
1 year	8	11
> 1 year	11	15
Unspecified	11	15
Intervention strategies		
Education only	23	32
Environmental remediation only	22	31
Education and environmental remediation	25	35
Other	2	3
Stakeholder involvement		
Yes	11	15
None or no information	61	85

TABLE 4—Intervention Evaluation

	No. Studies	% of Studies
Sample and evaluation design[a]		
Sample drawn from larger population	38	53
Randomization to intervention	35	49
Comparison group	44	61
Data-collection periods		
Preintervention	61	85
Postintervention (immediately after intervention)	31	43
Follow-up (several months after intervention)	56	78
Data-collection methods[a]		
Environmental sampling	29	40
Survey/interview/observation	40	56
Physiological measures	11	15
Document review	21	29
Evaluator		
Internal evaluator	56	78
External evaluator	16	22
Baseline disease incidence or prevalence in the community reported		
Yes	32	45
No	40	56
Documented improvements in outcome measures		
Yes	58	81
No (intervention was ineffective)	8	11
Not evaluated	6	8
Results		
Statistically significant	49	68
Not statistically significant	6	8
Statistical significance not tested	17	24
Improvements sustained over time		
Yes	37	51
No (conditions remained the same or worsened)	14	19
Not tested	21	29
Author's assessment of effectiveness		
Very successful	10	14
Moderately successful	53	74
Unsuccessful	9	13
Barriers to success[a]		
Participants' knowledge/awareness	18	25
Housing/environmental characteristics	18	25
Implementation/technological/resource problems	11	17
Participant characteristics (e.g., SES, health status)	17	24
Political/legal constraints	8	12
Inadequate resources	18	25
Attitudinal (e.g., stigma/discrimination	5	7
No barriers mentioned	9	13

Note. SES = socioeconomic status.
[a]Multiple responses permitted; percentages are reported as percentage of total studies (n = 72).

tion *(postintervention measures),* and 78% collected information on outcome measures several months after the intervention was completed *(follow-up measures).* Eighty-three percent of the studies reported tests of statistical significance. Sixty-eight percent reported statistically significant results. More than 80% documented improvements in the main outcome measures; 11% showed that outcomes either remained the same or worsened. Only about half the studies demonstrated that effectiveness could be sustained over time. Although findings reached statistical significance, relatively few authors (14%) rated the interventions as highly successful. However, the vast majority of authors (73%) concluded that their projects were at least somewhat successful. More than three quarters of the authors discussed barriers to successful implementation/maintenance. A wide range of factors were cited, including those related to participant characteristics and environmental, structural, technical, and larger economic and social factors.

QUALITIES OF SUCCESSFUL INTERVENTIONS

Looking across all the intervention studies, several factors seem generally related to success. First, only 2 studies examined policy interventions, but these seemed to be relatively cost-effective.[31,32] Second, technological interventions appear most successful when the technology is effective, cheap, and durable and requires little effort to maintain or use. Such interventions are especially effective if accompanied by behavioral or knowledge training, and if hazard amelioration can be successfully accomplished through individual-level efforts alone, for example, fire detectors[33] and scald-prevention devices.[34] Information and counseling may increase the presence of inexpensive, readily available improvements, but not those requiring larger investments.[23,24,35] Third, involving people more deeply in the solution of health problems, especially by home visits, appears to be especially effective and can improve multiple health outcomes,[28,29,36,37] promote fuller human development, improve social functioning,[25,28–30] and potentially increase psychological well-being as well.

LIMITATIONS OF RESEARCH

Our study had several limitations. It is based only on articles published in peer-reviewed journals and thus represents a limited portion of interventions actually carried out. It is restricted to those studies that intended to improve health by modifying housing, excluding interventions that might have had this unintended consequence, for example, income support policies that provide resources that can be used to improve housing conditions. Given the limitations of search engines and electronic databases, it is possible that our criteria missed some articles that would have met our inclusion criteria. In addition, we did not correspond with authors of the studies to collect additional information. Because the studies examined different housing exposures and health outcomes at different levels of organization (e.g., individual, housing unit, building, and block) and used different research methods, it was not possible to conduct a meta-analysis using pooled data. Despite these limitations, the interventions we did review met 2 important criteria: they succeeded in obtaining funding from public or private sources to carry out the interventions, and the reports were accepted by peer-reviewed journals. Thus, the articles represent what key stakeholders (e.g., funders, reviewers, and editors) deemed to be important findings on US housing interventions to improve health.

STRENGTHS AND WEAKNESSES OF INTERVENTION LITERATURE

Our review of evaluation methods suggests some strengths and several weaknesses. Most studies met the basic standards of identifying measurable objectives, collecting systematic data on specific housing conditions and health outcomes, and using acceptable methods to assess success in achieving outcomes. In part, the ability to meet these standards was facilitated by a narrow conceptualization of the research.

Few studies provided detailed information on the content of interventions or provided adequate contextual information (e.g., race/ethnicity and socioeconomic status of the target population were unspecified in more than half the studies), limiting generalizability. Most studies measured only the outcomes of interventions, not the processes that led to them, thus limiting their utility for designing other interventions or replication. As noted in another recent review, although several studies showed gains in individual health outcomes, confidence in findings is limited by small study populations and lack of controlling for confounders.[18]

TOWARD ECOLOGICAL INTERVENTIONS

The published housing interventions primarily sought to improve a single health condition by ameliorating environmental conditions, changing individual behavior or knowledge, or both. Only a few studies incorporated ecological paradigms, as many researchers now advocate.[38] In the ecological paradigm, behavior, the physical and social environment, and health dynamically connect the individuals, households, buildings, and communities.[39,40] An ecologically sensitive intervention takes into account the nested structure of the environment in which different scales influence each other. Physically, this includes housing conditions (e.g., vermin, lead dust),[41] homes within multifamily buildings,[42] all located in neighborhoods within particular settlement forms.[17] Socially, target individuals are situated in households, communities, and political units.[43]

This principle is illustrated in several of the successful home visit interventions, in which the home was seen as an important setting in which multiple health-related behaviors occur and that potentially contains both health-promoting and hazardous elements. These interventions[25,28–30] support changes in the physical environment and the recipient's behavior within the context of the habits, abilities, and life goals of the individual and the family. For example, the Department of Housing and Urban Development's Moving to Opportunity

demonstration project showed that families who moved away from public housing found better dwelling conditions and safer neighborhoods, leading to less crime victimization, injury, and asthma attacks among children.[17,26,27] These findings suggest that interventions could lead to more significant environmental and health effects if they were directed toward the broader goals of decent and affordable housing for all households and better opportunities for human development.

Ecological interventions are conceived as functional relationships among professionals, household members, communities, and political units. Some successful injury-reduction interventions illustrate this approach by connecting elderly participants more closely with supportive friends and family who reinforced the training and provided social rewards.[25,30] Only a few interventions incorporated participatory approaches, in which various stakeholders join in identifying goals, implementing research, and interpreting findings.[44–46]

Apart from these examples, most studies intervened on single, individual-level factors, in isolation; examined only 1 or 2 levels of social organization; and failed to use the more sophisticated analytic techniques such as multilevel modeling to understand the separate influences of different levels of analysis and interactions among levels.[47] These omissions may account, in part, for the lack of sustained improvements in, for example, interventions to eliminate cockroaches and rodents. Because many studies failed to examine the effectiveness of interventions over time, ecological constraints on the long-term efficacy of other interventions may have gone undetected.

By and large, the studies do not evaluate the multiple pathways by which housing influences health, comparing, for example, the relative roles of the physical and social environment in housing-related health problems. Consequently, there is now no way of assessing the value of, say, individual-level-only versus policy-only versus multilevel interventions. Nor is it possible to compare the effectiveness of housing versus other health-promoting interventions (e.g., dietary changes, alcohol and tobacco reduction). Such comparative studies might help policymakers decide how best to invest limited resources.

FROM EFFICACY TO EFFECTIVENESS

Finally, few interventions moved from efficacy to effectiveness studies. The greatest public health benefits are likely to result from interventions that can be applied in many settings, overcome common institutional and political obstacles, and reach significant portions of the vulnerable populations. The broad-based health improvements found in studies that had the primary goal of, for example, improving the life chances of poor, at-risk families[48] suggest that we need to know more about the public health implications of housing ecologies that include educational opportunities and support for child rearing, and so forth, that go beyond the usual definition of housing-based public health initiatives. Future studies on housing and health need to address these questions more systematically.

CONCLUSIONS AND RECOMMENDATIONS

The studies reviewed here have shown that changes in residents' knowledge, attitudes, and behavior; the household environment; public policy; and community norms can all contribute to improvements in housing-related health outcomes. The successes and the limitations of the interventions reviewed suggest some new directions that might prove fruitful. It is likely that interventions that combine activities to make changes at several of these levels and examine multiple health outcomes will be more effective than those working at single levels. Unfortunately, this hypothesis has yet to be tested systematically. Most interventions we reviewed could benefit from greater attention to acknowledged basic principles of health promotion such as the use of multiple strategies, the inclusion of participants in planning and implementation, and the importance of intervention intensity and duration.[16,38,49,50] The promising results from the few policy-change studies provide a rationale for increased attention to this strategy and support recent calls for more attention to this arena, especially as it relates to enforcement of housing codes.[4]

More ecologically grounded interventions should be tested to increase efficacy and overcome the limitations identified in this review and in the epidemiological literature.[16,42,49–51] The interdisciplinary nature of the ecological paradigm[52] requires understanding the cultural and socioeconomic dynamics of housing markets and housing production that affect housing access, quality, costs, ownership forms, and settlement patterns and have implications for physical health, psychosocial well-being, and the interaction of physical and psychosocial health.[17,53] Intervention and evaluation strategies developed in other fields may have useful applications for public health in addressing multilevel phenomena.[54,55] At the same time, it must be acknowledged that multilevel interventions can be difficult to implement, be more costly in the short run, and require more time to address the concerns of the multiple stakeholders. Public health leadership may be needed to gain support for this approach.

In conclusion, this review of the literature demonstrates that it is possible to design and carry out interventions that can lead to improved health by making changes in housing-related conditions. The successes and limitations of these efforts provide a foundation for designing a more systematic and coordinated research agenda that can inform the next generation of studies. By incorporating ecological approaches and health-promotion principles, future studies may be able to make additional improvements in housing conditions that lead to better health. ■

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Contributors

S. Saegert conceptualized the project; oversaw the coding, analysis, and housing journal database search; wrote the Discussion; and was responsible for the final draft. S. Klitzman conceptualized the project; oversaw the database search, coding, and analysis; wrote the Results; made tables; and edited the final draft. N. Freudenberg conceptualized the project, oversaw the coding and analyses, and wrote the Introduction. J. Cooperman-Mroczek searched databases, screened articles, coded data, performed analyses, wrote the Methods, and participated in discussions of the findings and interpretation. S. Nassar searched databases, screened articles, coded data, performed analyses, worked with S. Klitzman on the Results and tables, and participated in discussions of the findings and interpretation.

References

1. Blackmar E. Accountability for public health: regulating the housing market in nineteenth century New York City. In: Rosner D, ed. *Hives of Sickness: Public Health and Epidemics in New York City.* Brunswick, NJ: Rutgers University Press; 1995:42–64.

2. Rosen G. *A History of Public Health.* New York, NY: MD Publications; 1958:489–492.

3. Griscom J. *The Sanitary Condition of the Laboring Population of New York With Suggestions for Its Improvement.* New York: Harper & Bros; 1845.

4. Krieger J, Higgins D. Housing and health: time again for public health action. *Am J Public Health.* 2002;92: 758–768.

5. Matte T, Jacobs D. Housing and health—current issues and implications for research and programs. *J Urban Health.* 2000;77:7–25.

6. Fuller-Thomson E, Hulchanski JD, Hwang S. The health-housing relationship: what do we know? *Rev Environ Health.* 2000;15:109–134.

7. Evans GW, Wells NM, Chan H-YE, Saltzman H. Housing quality and mental health. *J Consult Clin Psychol.* 2000; 68:526–530.

8. Dunn JR, Hayes MV. Social inequality, population health and housing: a study of two Vancouver neighborhoods. *Soc Sci Med.* 2000;51:563–587.

9. Berkman LF, Kawachi I. *Social Epidemiology.* Oxford, England: Oxford University Press; 2000.

10. Leon D, Walt G. *Poverty, Inequality and Health: An International Perspective.* Oxford, England: Oxford University Press; 2001.

11. Diez-Roux A. Bringing context back into epidemiology: variables and fallacies in multilevel analysis. *Am J Public Health.* 1998;88:216–222.

12. Matteson DM, Burr JA, Marshall JR. Infant mortality: a multi-level analysis of individual and community risk factors. *Soc Sci Med.* 1998;47:1841–1854.

13. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science.* 1997;277:918–924.

14. Subramanian SV, Kim DJ, Kawachi I. Social trust and self-rated health in US communities: a multilevel analysis. *J Urban Health.* 2002; 79(suppl 1):S21–S34.

15. Gordis L. From association to causation: deriving inferences from epidemiologic studies. In: *Epidemiology.* Philadelphia, Pa: WB Saunders Co; 2000; 184–203.

16. Freudenberg N, Silver D, Carmona JM, Kass D, Lancaster B, Speers M. Health promotion in the city: a structured review of the literature on interventions to prevent heart disease, substances abuse, violence and HIV infection in US metropolitan areas, 1980–1985. *J Urban Health.* 2000;77:443–457.

17. Saegert S, Evans GW. Poverty, housing niches and health. *J Soc Issues.* In press.

18. Thomson H, Petticrew M, Morrison D. Health effects of housing improvement: a systematic review of intervention studies. *BMJ.* 2001;323:187–190.

19. Martens WH. A review of physical and mental health in homeless persons. *Public Health Rev.* 2001;29:13–33.

20. Robertson MJ, Winkleby MA. Mental health problems of homeless women and differences across subgroups. *Annu Rev Public Health.* 1996;17:311–336.

21. Moore J. Health and home for homeless people in transition. *Rev Environ Health.* 2000;15:135–148.

22. Power R, French R, Connelly J, et al. Health, health promotion, and homelessness. *BMJ.* 1999;318:590–592.

23. Plautz B, Beck DE, Selmar C, Radetsky M. Modifying the environment: a community-based injury-prevention program for elderly residents. *Am J Prev Med.* 1996;12:33–38.

24. Schwarz DF, Grisso JA, Miles C, Holmes JH, Sutton RL. An injury prevention program in an urban African-American community. *Am J Public Health.* 1993;83:675–680.

25. Weber J, Kehoe T, Bakoss M, Kiley M, Dzigiel JM. Safety at home: a practical home-injury control program for independent seniors. *Caring.* 1996;15: 62–66.

26. Katz LF, Kling JR, Liebman JB. Moving to Opportunity in Boston: early results of a randomized mobility experiment. *Q J Econ.* 2001;607–653.

27. Rosenbaum E, Harris LE. Low-income families in their new neighborhoods: the short-term effects of moving from Chicago's public housing. *J Fam Issues.* 2001;22:183–210.

28. Olds DL, Henderson CR, Kitzman H. Does prenatal and infancy nurse home visitation have enduring effects on qualities of parental caregiving and child health at 25 to 50 months of life? *Pediatrics.* 1994;93:89–98.

29. Olds DL, Henderson CR, Kitzman H, Cole R. Effects of prenatal and infancy nurse home visitation on surveillance of child maltreatment. *Pediatrics.* 1995;95:365–371.

30. Bezon J, Echevarria KH, Smith GB. Nursing outcome indicator: preventing falls for elderly people. *Outcomes Manag Nurs Pract.* 1999;3:112–116.

31. Cummings P, Grossman DC, Rivara FP, Koepsell TD. State gun safe storage laws and child mortality due to firearms. *JAMA.* 1997;278:1084–1086.

32. Brown MJ, Gardner J, Sargent JD, Swartz K, Hu H, Timperi R. The effectiveness of housing policies in reducing children's lead exposure. *Am J Public Health.* 2001;91:621–624.

33. Mallonee S, Istre GR, Rosenberg M, et al. Surveillance and prevention of residential fire injuries. *N Engl J Med.* 1996;335:27–31.

34. Fallat MD, Rengers SJ. The effect of education and safety devices on scald burn prevention. *J Trauma.* 1993:34: 560–564.

35. Quinlan KP, Sacks JJ, Kresnow M. Exposure to and compliance with pediatric injury prevention counseling—United States, 1994. *Pediatrics.* 19981; 102:e55.

36. Kitzman H, Olds DL, Henderson CR, et al. Effect of prenatal and infancy home visitation by nurses on pregnancy outcomes, childhood injuries, and repeated childbearing. *JAMA.* 1997;278: 644–652.

37. Schultz R, Pawel D, Murphy A. A retrospective examination of in-home educational visits to reduce childhood lead levels. *Environ Res.* 1999;80: 364–368.

38. Smedley BD, Syme SL, eds. *Promoting Health: Intervention Strategies from Social and Behavioral Research.* Washington, DC: Committee on Capitalizing on Social Science and Behavioral Research to Improve the Public's Health, Division of Health Promotion and Disease Prevention; 2001.

39. Saegert S, Winkel GH. Social capital and the revitalization of New York City's distressed inner-city housing. *Housing Policy Debate.* 1998;9:17–60.

40. Saegert S, Winkel GH, Swartz C. A prospective study of social capital and crime in low-income housing. *Housing Policy Debate.* 2002;13:186–226.

41. Roberts JW, Clifford WS, Glass G, Hummer PG. Reducing dust, lead, dust mites, bacteria, and fungi in carpets by vacuuming. *Arch Environ Contam Toxicol.* 1999;36:477–484.

42. Rauh V, Chew GL, Garfinkel RS. Deteriorated housing contributes to high cockroach allergen levels in inner-city households. *Environ Health Perspect.* 2002;110(suppl 2):323–327.

43. Olds DL, Hill PL, O'Brian R, Racine D, Moritz P. Taking preventive intervention to scale: the nurse-family partnership. *Cogn Behav Sc.* In press.

44. Minkler M, Wallerstein N, eds. *Community-Based Participatory Research for Health.* New York: John Wiley & Sons; 2002.

45. Green LW, Mercer SL. Can public health researchers and agencies reconcile the push from funding bodies and the pull from communities? *Am J Public Health.* 2001;91:1926–1929.

46. Israel BA, Schulz AJ, Parker EA, Becker AB. Review of community-based research: assessing partnership approaches to improving public health. *Annu Rev Public Health.* 1998:19: 173–202.

47. Bryk AS, Raudenbush SW. *Hierarchical Linear Models: Applications and Data Analysis Methods.* Newbury Park, Calif: Sage Publications; 1992.

48. Brooks-Gunn J, Duncan GJ, Aber JL. *Neighborhood Poverty.* Vols 1 and 2. New York: Russell Sage; 1997.

49. Green LW, Richard L, Potvin L. Ecological foundations of health promotion. *Am J Health Promot.* 1996;10: 270–281.

50. Brownson RC, Baler EA, Novick LF. *Community-Based Prevention: Programs That Work.* Gaithersburg, Md: Aspen Publications; 1999.

51. Macintrye S, Ellaway A. Ecological approaches: rediscovering the role of the physical and social environment. In: Berkman LF, Kawachi I, eds. *Social Epidemiology.* Oxford, England: Oxford University Press; 2000:332–348.

52. Bronfenbrenner U. Toward an experimental ecology of human development. *Am Psychol.* 1977;32:513–531.

53. Saegert S. The role of housing in the experience of dwelling. In: Altman I, Werner C, eds. *Home Environments.* New York: Plenum Publishing Corp; 1986. *Human Behavior and Environments.* Vol 8.

54. Shinn M. Special issue: ecological assessment. *Am J Community Psychol.* 1996;24:1–201.

55. Kellam SG, Koretz D, Moscicki EK. Special issue: prevention science, I. *Am J Community Psychol.* 1999;27:461–595.

Walking, Bicycling, and Urban Landscapes: Evidence From the San Francisco Bay Area

Some claim that car-dependent cities contribute to obesity by discouraging walking and bicycling. In this article, we use household activity data from the San Francisco region to study the links between urban environments and nonmotorized travel.

We used factor analysis to represent the urban design and land-use diversity dimensions of built environments. Combining factor scores with control variables, like steep terrain, that gauge impediments to walking and bicycling, we estimated discrete-choice models. Built-environment factors exerted far weaker, although not inconsequential, influences on walking and bicycling than control variables.

Stronger evidence on the importance of urban landscapes in shaping foot and bicycle travel is needed if the urban planning and public health professions are to forge an effective alliance against car-dependent sprawl. (*Am J Public Health.* 2003;93:1478–1483)

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URBAN PLANNERS AND PUBLIC health advocates alike decry sprawl for prodding Americans to drive their cars from anywhere to everywhere.[1,2] Car-dependent cities and suburbs, critics charge, spawn a sedentary lifestyle and associated health problems such as obesity, adding as much as $76 billion annually to US medical expenses by one estimate.[3] Eight-lane thoroughfares, serpentine roads, incomplete sidewalk networks, far-flung retail plazas, campus-style business parks, and other distinguishing traits of contemporary America are said to conspire against walking and bicycling. However, are their influences serious enough to warrant radical changes in how we design communities of the future?

Numerous studies have examined the effects of built environments on motorized travel; however, far less attention has been given to impacts on walking and bicycling.[4,5] Probing effects on nonmotorized transport requires a different analytic approach. For one thing, walking and bicycle trips are usually shorter than those made by car or public transit, requiring a finer analytic resolution. Geographic information system (GIS) tools help in this regard, especially if one knows the longitudinal-latitudinal coordinates of trip origins and destinations. Additionally, choice models of motorized travel normally include comparative highway travel times of competing modes in their utility specifications.[6] This is because trip durations often vary substantially between the private car and public transit. For nonmotorized transport, and especially walking, speeds tend to be so much slower than by car, train, or bus that travel-time differentials are meaningless. Because people of a similar age and stature usually walk at comparable speeds, and given that pedestrians perceive trip making mainly in spatial terms, distance is a more suitable measure of impedance.[7]

As important to the question of model specification is the inclusion of factors that represent potential barriers to walking or bicycling.[8] Besides distance, these include steep slopes, nightfall, precipitation, and less secure environs. Failure to include such factors can compromise the internal and construct validity of the research. For example, curvilinear and cul-de-sac street layouts that discourage walking are particularly common in hilly terrain.[9] Ignoring topography means that associated variables, such as road designs, that are included in a predictive model end up absorbing the influences of this omitted but relevant variable. Assigning health benefits to built environments necessitates a valid model specification that nets out impedance factors such as the presence of a steep terrain.

In this study, the influences of urban designs, land-use diversity, and density patterns on the choice to walk or bicycle, vis-à-vis other factors, are examined using year-2000 data for the San Francisco Bay Area. The work builds upon other research that has applied the "3D" principle (density, diversity, and design) to associate travel choices with built environments.[10–12] We close the article with a discussion of the public health and urban planning implications of the research findings.

DATA AND METHODS

The chief database used to carry out this research was the 2000 Bay Area Travel Survey (BATS), which contains up to 2 days of daily activity information for members of 15 066 randomly selected households in the 9-county San Francisco Bay Area.[13] Household activity surveys provide rich details on everyday activities of all household members, including travel and out-of-home activities. To narrow our investigation to trips that were potentially walkable or bikable, we limited the analysis to purposes that were unlikely to involve carrying significant amounts of items or goods, such as groceries. Accordingly, records for the following out-of-home activities were selected: socialize/visit friends; meals/eating; personal services (e.g., banking); recreation/entertainment; volunteer/civic/religious activities; and shopping away from home (under 15 minutes in duration). Because BATS did not reveal the exact nature of shopping, we imposed a 15-minute limit, as an upper bound, under the assumption this would correspond to a walkable convenience shop trip. One quarter of all sampled shop activities took fewer than 15 minutes, and 94%

of shop destinations reached by foot were below this benchmark. Also, only records for trips that did not begin at a workplace were selected; in most instances, trip origins corresponded to people's residences. A final refinement was the selection of trip records of less than 5 miles, a potentially walkable distance range that encompassed 88% and 96% of sampled bicycling and walking trips, respectively. These refinements yielded a sample frame of 7889 trip records.

Each trip record contained information on the purpose; mode; time of day; day of week; origin and destination longitudinal-latitudinal coordinates; and other features of the journey. Attributes of trip makers (e.g., gender) and their households (e.g., vehicle availability) were obtained from the BATS personal and household data files and linked to each trip record. Data on built-environment and control variables were collected for year 2000 to match up with BATS travel records. Average slope (rise/run) was calculated based on the elevations of trip origins and destinations. Recorded times of trip departures and arrivals, matched against sunrise and sunset information for the Bay Area, produced a dummy variable on whether trips occurred during nightfall. Information on neighborhood crime rates and social conditions would have been a preferred measure of "safety and security"; however the unavailability of geocoded data within a consistent 1-mile radius of trip origins and destinations precluded this. An admittedly less-than-ideal proxy for "neighborhood quality"—the proportion of households with annual incomes below $25 000 within a 1-mile radius of trip origins and destinations—was used instead.

Data on neighborhood attributes, such as median household incomes, were obtained from the 2000 census. Information on employment by occupations (used to gauge land-use mixture) was acquired from the Association of Bay Area Governments, stratified by census tract.[14]

For each trip record, density and land-use composition were imputed for 1-mile and 5-mile radii of origins and destinations using block-level data and GIS tools. Because many walking and bicycle trips are beyond 1 mile in length, we distinguished land-use attributes at both the origins and the destinations of trips. Variables related to street and urban design characteristics within 1-mile radii of trip origins and destinations, such as counts of 3-way intersections and lineal miles of local streets, were computed from 2000 census topologically integrated geographic encoding and referencing (TIGER) files. Having numerous 3-way intersections equates to neighborhoods populated by T-intersections, curvilinear streets, and cul-de-sacs, whereas areas with all 4-way intersections and small quadrilateral blocks have gridiron, usually pedestrian-friendly, street patterns.[15,16] We turned to discrete-choice logit modeling, of the following form, to estimate the probability Bay Area residents walked or bicycled:

$$(1)\ P_{niod} = \exp(V_{niod}) / [\Sigma_{j \in Cnod} \exp(V_{njod})],\ \forall\ V_{niod} = f(I_{od}, PH_n, BE_o, BE_d)$$

where

P_{niod}=probability of person n choosing mode i for traveling between origin o and destination d

C_{nod}=choice set of modes available to person n traveling between origin o and destination d

V_{niod}=utility function for person n traveling by mode i between origin o and destination d

V_{njod}=utility function for person n traveling by mode j between origin o and destination d

I_{od}=impedance vector for trips from origin o to destination d, including distance and slope

PH_n=personal and household characteristics vector for trip maker n (e.g., gender, vehicle availability)

BE_o=built-environment vector for 1- or 5-mile radius of origin o, representing measures of land-use intensity, land-use mixture, land-use accessibility, and walking quality

BE_d=built-environment vector for 1- or 5-mile radius of destination d, comparable to the vector for origin o

Our operative hypothesis is that BE_o and BE_d are significant explainers of the decision to walk or ride a bicycle, controlling for I_{od} and PH_n. Because of high intercorrelations among variables in these vectors, we turned to factor analysis to express BE_o and BE_d. The SAS software package (SAS Institute Inc, Cary, NC) was used for both discrete-choice modeling and factor extraction.

FACTOR ANALYSIS

The core dimensions of built environments—density, diversity, design—are not easily captured by a single variable. However, when multiple variables are used to express elements such as street design and land-use mixture, multicollinearity problems often contaminate model estimation. As in several previous studies of built environments and travel, we turned to factor analysis to resolve this problem.[10,17–19] Using variables on street supply, intersection configurations, city block sizes, and housing/employment characteristics within 1-mile radii of trip origins and destinations, we extracted 4 interpretable factors that exhibited Thurstone's "deep structure" (with eigenvalues above 1).[20] Principal components estimation and varimax rotation were used in deriving the results shown in Table 1. Together, these factors accounted for more than two thirds of the variance among the 18 variables listed in the table.

The first 2 factors pertain to street and city block characteristics—one factor for the trip origin, the other for the destination. We call these *pedestrian-/bicycle-friendly* factors because positive signs on loadings reflect urban design characteristics that are conducive to walking and bicycling. The block-size/intersection attributes of trip origins had the highest commonality among factors (eigenvalue of 3.86), accounting for 21.5% of total variance. Factor loadings reveal that areas with large city blocks are not pedestrian-/bicycle-friendly environs. Neither are neighborhoods with large shares of 3-way intersections and dead-ends, signs of nongrid street patterns. On the other hand, areas dotted with 4-way intersections (denoting gridiron street patterns) as well as intersections with 5 or more converging streets (suggesting even higher levels of connectivity) were positively associated with the pedestrian-/bicycle-friendly factor.

The third and forth factors reflect land-use diversity of trip origins and destinations. Neighborhoods with heterogeneous

TABLE 1—Factor Analysis Loadings and Summary[a]

	Pedestrian-/ Bike-Friendly Design Factor, Origin	Pedestrian-/ Bike-Friendly Design Factor, Destination	Land-Use Diversity Factor, Origin	Land-Use Diversity Factor, Destination
Square meters per block within 1 mile, average; origin	–0.480			
Square meters per block within 1 mile, average; destination		–0.327		
Three-way intersections, proportion of total intersections within 1 mile; origin	–0.942			
Three-way intersections, proportion of total intersections within 1 mile; destination		–0.952		
Four-way intersections, proportion of total intersections within 1 mile; origin	0.933			
Four-way intersections, proportion of total intersections within 1 mile; destination		0.943		
Five-or-more–way intersections, proportion of total intersections within 1 mile; origin	0.690			
Five-or-more–way intersections, proportion of total intersections within 1 mile; destination		0.677		
Dead ends as proportion of total intersections within 1 mile; origin	–0.890			
Dead ends as proportion of total intersections within 1 mile; destination		–0.873		
Mixed use entropy (within 1 mile), at origin[b]			0.826	
Mixed use entropy (within 1 mile), at destination[b]				0.828
Employed residents–to–jobs balance index (within 1 mile of origin)[c]			0.871	
Employed residents–to–jobs balance index (within 1 mile of destination)[c]				0.802
Employed residents–to–retail/services balance index (within 1 mile of origin)[d]			0.884	
Employed residents–to–retail/services balance index (within 1 mile of destination)[d]				0.873
"Residentialness" index, origin[e]				–0.879
"Residentialness" index, destination[e]				–0.773
Summary statistics:				
Eigenvalue	3.86	3.51	2.54	2.39
Percentage of variance	21.47	19.50	14.11	13.27
Cumulative percentage of variance captured by factors = 68.34%				

[a]Only loadings > 0.20 are shown.
[b]Mixed use entropy (within 1 mile) = $-1*\{[\Sigma_i (p_i) (\ln p_i)]/\ln k\}$, where p = proportion of total land uses; k = category of land use (single-family housing units, multifamily housing units, retail/service employment, office employment, manufacturing/trade/other employment); ln = natural logarithm.
[c]Employed residents–to–jobs balance index (within 1 mile of origin) = 1 – {[ABS(ER – JOBS)] /(ER + JOBS)}, where ABS = absolute value; ER = number of employed residents; JOBS = number of workers.
[d]Employed residents–to–retail/services balance index (within 1 mile of origin) = 1 – {[ABS(ER – RS)]/(ER + RS)}, where ABS = absolute value; ER = number of employed residents; RS = number of retail/service jobs.
[e]Where "residentialness" index = housing units as proportion of total employment and housing units.

mixes of single-family and multifamily housing as well as jobs spread across the retail/service, office, and manufacturing/trade/other sectors scored high on these factors (based on the 0–1 entropy index, wherein 1 represents maximal heterogeneity). So did areas with a balance of employed residents and jobs within 1-mile radii (based on the 0–1 balance index, wherein 1 represents perfect balance). Indexes reflecting a balance of retail/service activities relative to employed residents within 1-mile radii of origins and destinations also scored high on the diversity factor. These indexes are considered to be particularly relevant because they reflect the relative availability of retail shops and consumer services within 1-mile (and thus plausibly walkable) radii of origins and destinations. Lastly, indexes denoting the degree to which neighborhoods are residential in character loaded negatively onto the diversity factor. This accounts for the fact that bedroom communities (predominantly residential places) are usually not land-use–rich settings, whereas areas with higher shares of nonresidential activities often are.

We note that other extracted factors (not shown in Table 1 because of low eigenvalues) captured some aspects of land-use intensity, such as population and employment densities; however, loadings on these factors were fairly small and not always interpretable. To a significant extent, density attributes of neighborhoods are captured in what we are calling the *design and diversity factor*s, that is, neighborhoods with small blocks, grid street patterns, and mixed uses also tend to be fairly dense.

RESULTS

Walking-Choice Model

Walking constituted 12.5% of surveyed BATS trips that were 5 miles or less for the trip purposes studied. Far more common was travel by automobile, van, or motorcycle, constituting 82.6% of the total. Even for trips under 1 mile, the car dominated, making up 60.7% of the total (compared with 34.3% for walking).

The best-fitting walking-choice model, shown in Table 2, presents the estimated coefficients that appear in the variables of each vector in equation 1. The coefficients reflect the direction in which each variable influences the walking-choice—positive values denote that a variable increases the probability of walking whereas negative values indicate the opposite. Table 2 reveals that control variables had appreciably stronger predictive powers than built-environment factors in explaining whether Bay Area residents traveling under 5 miles walked or not. Trip purpose weighed in heavily, with social and recreation/entertainment activities, in particular, increasing the likelihood that people walked. Weekends also favored walking. Personal attributes likewise mattered. Predictably, those with physical disabilities and numerous cars in the household were less likely to walk. More surprising was the ethnic/racial dimension. Even after controlling for a socioeconomic factor like vehicle ownership levels, African Americans were more likely to walk than were Whites or Asian Americans. (This is consistent with 2000 census results showing higher shares of African Americans [3.2%] walked to work than the typical American worker [2.9%][21]; for all trip purposes, African Americans averaged 82% more walking trips in 1995 than Whites.[22]) Further, males tended to walk more than females, all else being equal.

TABLE 2–Walking-Choice Model for Predicting the Probability That a Trip Will Be Made by Walking

	Coefficient	Standard Error	Probability
Constraints/deterrents			
Trip distance (miles)	–1.970	0.074	.000
Slope (rise/run)	–4.109	2.090	.049
Rainfall day of trip (inches in 24 hours)	–0.729	0.330	.027
Dark (1 = yes, 0 = no) (before sunrise or after sunset)	–0.158	0.112	.159
Low-income neighborhood (proportion of households within 1 mile of origin and destination with annual incomes < $25 000)	–0.766	0.523	.143
Personal/household attributes			
Disability (1 = yes, 0 = no)	–0.480	0.275	.081
Gender (1 = male, 0 = female)	0.161	0.083	.051
African American (1 = yes, 0 = no)	0.788	0.278	.005
Asian American (1 = yes, 0 = no)	–0.286	0.192	.136
White (1 = yes, 0 = no)	–0.310	0.118	.008
Number of vehicles in household	–0.695	0.050	.000
Trip characteristics			
Weekend trip (1 = yes, 0 = no)	0.246	0.100	.013
Recreation/entertainment purpose (1 = yes, 0 = no)	0.809	0.120	.000
Eating/meal purpose (1 = yes, 0 = no)	0.688	0.127	.000
Social purpose (1 = yes, 0 = no)	0.886	0.144	.000
Shopping purpose (1 = yes, 0 = no)	0.623	0.165	.000
Built-environment characteristics			
Employment accessibility: number of jobs (in 10 000s) within 1 mile of origin	0.068	0.042	.104
Pedestrian-/bike-friendly design factor, origin	0.037	0.048	.441
Pedestrian-/bike-friendly design factor, destination	0.035	0.047	.465
Land-use diversity factor, origin	0.098	0.042	.021
Land-use diversity factor, destination	0.023	0.042	.590
Constant	1.217	0.198	.000
Summary statistics:			
No. of cases = 7836			
χ^2 = 2 010.5 (probability = .000)			
ρ^2: $1 - L(1)/L(0) = 0.429$			

Five impedance factors entered the model, reflecting walking disutilities in the logit formulation. Even within a 5-mile distance band, the likelihood of walking eroded steadily with the length of the trip. Steep terrain, rain, and nightfall also deterred walking. The model further suggests that pedestrians tended to shy away from lower-income settings, presumably because of safety concerns.

The only built-environment factor significant at the 5% probability level was land-use diversity at the trip origin (which in most instances corresponded to a 1-mile radius of a person's residence). Balanced, mixed-use environs with retail services significantly induced walking, other things being equal. Similarly, land-use diversity at the destination generally encouraged walking; however, this relation was statistically weak. On the other hand, pedestrian-/bicycle-friendly designs at neither the origin nor destination had much bearing on mode choice. Evidently, the microdesign elements of neighborhoods examined in this study, such as intersection configurations and block sizes, exerted fairly inconsequential influences on walking. Only slightly more important, although still statistically insignificant, was employment density within 1 mile of a person's residence (reflected by the isochronic measure of job accessibility).

These results are consistent with those of previous studies suggesting that density (as reflected by the employment accessibility variable) and land-use diversity exert stronger pressures than urban design on the decision to walk.[5,10,12] This is even after introducing far more control variables that account for walking impedances than in the case of previous studies. The findings also align with earlier studies that show that travel choices depend as much, if not more, on the degree of land-use mixing as urban densities.[5,23] Perhaps most notably, these results parallel other research findings that show that land-use factors exert fairly modest influ-

ences on travel behavior in comparison to the demographic characteristics of trip makers and impedances factors like distance and travel time.[4]

Bicycle-Choice Model

Only 1.5% of BATS trips 5 or fewer miles (for the subsampled nonwork trip purposes) were by bicycle. (For trips beyond 5 miles, the share was nearly identical.) For recreation/entertainment trips of 5 miles or less, bicycling captured a higher market share, 2.3% of all journeys. Bicycling is generally more popular in the Bay Area than in other parts of the United States. In 1995, just 0.9% of US trips were by bicycle.[24]

The binomial choice mode for bicycle trips, shown in Table 3, produced results that were fairly similar to those of the walking-choice model, although built-environment factors emerged as generally stronger predictors. The influences of control variables were akin to those of the walking-choice model with a few exceptions: weekend and shopping trips were more weakly related to bicycling; the only reasonably significant ethnic/racial variable was African Americans; the slope was less and nightfall was more of a deterrent to bicycling; rainfall generally did not dissuade people from bicycling; and, predictably, the likelihood of bicycling increased with the number of bicycles in a person's household (just as studies show that driving increases with car ownership). This relationship is likely circular–that is, a desire to bicycle no doubt increases bicycle ownership.

Among built-environment features, the urban design and land-use diversity factors were positively associated with the decision to ride a bicycle. Although the relationships were not significant at the 5% probability level, design had a far stronger influence on bicycling than on walking choice. Block size, gridiron streets, and other design attributes were slightly more important to the decision to bicycle at the destination than the origin. Mixed land uses and balances of residences, jobs, and retail services also worked in favor of bicycling, although only to a notable degree at the origin of trips. The influence of density was less straightforward. Having appreciable retail/service activities within a 1-mile radius of a person's origin generally encouraged that person to bicycle. This isochronic metric of retail/service density captured the availability of nearby convenience retail outlets. Within a larger 5-mile radius of a trip origin, higher overall employment densities (as reflected by the employment-accessibility variable) deterred bicycle travel. Presumably this is because dense employment settings, like urban job centers and edge cities, often create numerous roadway conflict points and safety hazards for bicyclists.

TABLE 3—Bicycle-Choice Model for Predicting the Probability That a Trip Will Be Made by Bicycle

	Coefficient	Standard Error	Probability
Constraints/deterrents			
Trip distance (miles)	−0.291	0.084	.001
Slope (rise/run)	−7.796	5.930	.187
Dark (1 = yes, 0 = no) (before sunrise or after sunset)	−0.721	0.314	.022
Low-income neighborhood (proportion of households within 1 mile of origin and destination with annual incomes < $25 000)	−1.657	1.221	.175
Personal/household attributes			
Gender (1 = male, 0 = female)	0.588	0.194	.002
African American (1 = yes, 0 = no)	0.854	0.472	.071
Number of vehicles in household	−0.629	0.120	.000
Number of bicycles in household	0.345	0.037	.000
Trip characteristics			
Weekend trip (1 = yes, 0 = no)	0.226	0.219	.301
Recreation/entertainment purpose (1 = yes, 0 = no)	0.602	0.225	.001
Social purpose (1 = yes, 0 = no)	0.861	0.281	.002
Shop purpose (1 = yes, 0 = no)	0.443	0.389	.256
Built environment characteristics			
Employment accessibility: number of jobs (in 10 000s) within 5 miles of origin	−0.017	0.011	.106
Retail/service density: number of retail/service jobs per net commercial acre within 1 mile of origin	0.005	0.003	.114
Pedestrian-/bike-friendly design factor, origin	0.234	0.151	.122
Pedestrian-/bike-friendly design factor, destination	0.193	0.113	.088
Land-use diversity factor, origin	0.156	0.098	.112
Land-use diversity factor, destination	0.056	0.099	.570
Constant	−3.773	0.392	.000
Summary statistics:			
No. of cases = 7836			
χ^2 = 152.8 (probability = .000)			
$\rho^2 = 1 - L(1)/L(0) = .131$			

DISCUSSION

Previous research on how urban landscapes shape travel behavior can be faulted on a number of grounds, though none more so than questionable construct and internal validity of research designs. Many factors conspire against walking and bicycling in contemporary urban American, and car-dependent landscapes is just one of those factors. Unless factors like weather conditions or topography are controlled for, our understanding of how built environments influence travel will remain murky.

Our research reveals that urban landscapes in the San Francisco Bay Area generally have a modest and sometimes statistically insignificant effect on walking and bicycling. Although well-connected streets, small city blocks, mixed land uses, and close proximity to retail activities were shown to induce nonmotorized transport, various exogenous factors, such as topography, darkness, and rainfall, had far stronger influences. Other control variables, such as demographic characteristics of trip makers, were also far stronger predictors

of walking and bicycling choice than built-environment factors. From a public-policy standpoint, this suggests that a greater public health benefit might accrue from designing walkable neighborhoods that appeal to the niche-market characteristics of different demographic groups versus microdesigning places in hopes of swaying travel behavior. That is, pedestrian-friendly places suited to the taste preferences of sociodemographic groups might induce more physical activity over the long run through the process of residential self-selection than overt efforts to create compact, mixed-use, gridded-street neighborhoods throughout the cityscape. Market-responsive planning and zoning would help in this regard.

Among the built-environment factors in the models, land-use diversity in and around a person's neighborhood (e.g., the presence of neighborhood retail) was the strongest predictor of walking. Bicycling, on the other hand, was equally influenced by density, diversity, and design, especially at the origin (i.e., the residential end) of a trip. Because of the stronger statistical fits, our results hint that built environments exert bigger impacts on walking and bicycling in and around a person's residential neighborhood than do destinations. The evidence is suggestive although hardly compelling.

Might these results be generalizable beyond the Bay Area? We suspect so. Although factors like a hilly topography and Mediterranean climate are unique to the San Francisco region, given that these and other factors were controlled for in this study, the marginal impacts of built-environment elements, we suspect, are likely similar in other settings.

We do not rule out that the absence of strong statistical relationships in this study could reflect the use of imperfect variables to capture the myriad features of built environments. Although GIS tools enable physical attributes of neighborhood streets and blocks to be defined, other microdesign attributes of built environments, such as the presence of landscaping or street furniture (e.g., benches, light posts, bus shelters), were not examined because of data limitations. Other research suggests that such features generally exert minor influences on mode choices.[5,10,25,26] Still, statistical analyses like ours should be supplemented by microlevel analyses, including qualitative case studies and quasi-experimental comparisons, that account for possible influences of street-scale design elements.[27,28]

Although their motives are different, urban planners and public health officials form a potentially powerful alliance in the fight against car-dependent sprawl and the promotion of healthy cityscapes. However, more research is needed that clarifies the potential environmental benefits—whether cleaner air or healthier citizens—of altering urban landscapes if this alliance is to gain legitimacy. ■

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Contributors

R. Cervero designed and directed the research, carried out the statistical analyses, and wrote the article. M. Duncan constructed the database and assisted with some of the data analyses.

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References

1. Frank LD. Land use and transportation interaction: implications for public health and quality of life. *J Plann Education Res.* 2000;20: 6–22.

2. Schmid T, Pratt M, Howze E. Policy as intervention: environmental and policy approaches to the prevention of cardiovascular disease. *Am J Public Health.* 1995;85:1207–1211.

3. Pratt M, Macera CA, Wang G. Higher direct medical costs associated with physical inactivity. *Physician Sports Med.* 2000;28(10):63–70.

4. Crane R. The impacts of urban form on travel: a critical review. *J Plann Literature.* 2000;15:3–23.

5. Ewing R, Cervero R. Travel and the built environment: a synthesis. *Transportation Res Rec.* 2001;1780: 87–113.

6. Ben-Akiva M, Lerman S. *Discrete Choice Analysis: Theory and Application to Travel Demand.* Cambridge, Mass: MIT Press; 1985.

7. Untermann R. *Accommodating the Pedestrian: Adapting Towns and Neighborhoods for Walking and Bicycling.* New York: Van Nostrand Reinhold Co; 1984.

8. Bauman AE, Sallis JF, Dzewaltowski DA, Owen N. Toward a better understanding of the influences on physical activity: the role of determinants, correlates, causal variables, mediators, moderators, and confounders. *Am J Prev Med.* 2002;23(2S):5–14.

9. Lynch K. *Good City Form.* Cambridge, Mass: MIT Press; 1981.

10. Cervero R, Kockelman K. Travel demand and the 3Ds: density, diversity, and design. *Transportation Res D.* 1997; 2:199–219.

11. Walters G, Ewing R, Schroeer W. Adjusting computer modeling tools to capture effects of smart growth, or poking at the project like a lab rat. *Transportation Res Rec.* 2000; 1722:17–26.

12. Cervero R. Built environments and mode choice: toward a normative framework. *Transportation Res D.* 2002; 7:265–284.

13. MORPACE International Inc. *Bay Area Travel Survey 2000: Final Report.* Oakland, Calif: Metropolitan Transportation Commission; 2002. Data available at: ftp://ftp.abag.ca.gov/pub/mtc/planning/BATS/BATS2000. Accessed September 20, 2002.

14. *ABAG Projections 2002: City, County and Census Tract Forecasts 2000–2025.* Oakland, Calif: Association of Bay Area Governments; 2002.

15. Southworth M, Owens PM. The evolving metropolis: studies of community, neighborhood, and street form at the urban edge. *J Am Plann Assoc.* 1993;59:271–287.

16. Ewing R. *Best Development Practices.* Chicago: Planners Press; 1996.

17. Cervero R. *America's Suburban Centers: The Land Use-Transportation Link.* Boston: Unwin-Hyman; 1989.

18. Cambridge Systematics Inc. *The Effects of Land Use and Travel Demand Management Strategies on Commuting Behavior.* Washington, DC: US Department of Transportation, Technology Sharing Program; 1994.

19. Ewing R, Pendall R, Chen D. *Measuring Sprawl and Its Impacts.* Washington, DC: Smart Growth America; 2002.

20. Thurstone LL. *Multiple Factor Analysis.* Chicago: University of Chicago Press; 1947.

21. Ernst M, McCann B. *Mean Streets 2002.* Washington, DC: Surface Transportation Policy Project; 2002.

22. Hu PS, Young JR. *Summary of Travel Trends: 1995 Nationwide Personal Transportation Survey.* Washington, DC: US Department of Transportation, Federal Highway Administration; 1999.

23. Cervero R. Mixed land uses and commuting: evidence from the American Housing Survey. *Transportation Res A.* 1996;30:361–377.

24. Pucher J, Komanoff C, Schimek P. Bicycling renaissance in North America? Recent trends and alternative policies to promoting bicycling. *Transportation Res A.* 1999;33:625–654.

25. Crane R, Crepeau R. Does neighborhood design influence travel? A behavioral analysis of travel diary and GIS data. *Transportation Res D.* 1998;3: 225–238.

26. Handy S, Clifton K. Evaluating neighborhood accessibility: possibilities and practices. *J Transportation Statistics.* 2002;4:67–78.

27. Cervero R, Radisch C. Travel choices in pedestrian versus automobile-oriented neighborhoods. *Transport Policy.* 1996;3:127–141.

28. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activities: views from urban planning. *Am J Prev Med.* 2002;23(2S):64–73.

Health, Supportive Environments, and the Reasonable Person Model

The Reasonable Person Model is a conceptual framework that links environmental factors with human behavior. People are more reasonable, cooperative, helpful, and satisfied when the environment supports their basic informational needs. The same environmental supports are important factors in enhancing human health.

We use this framework to identify the informational requirements common to various health-promoting factors that are realizable through well-designed physical environments. Environmental attractors, support of way-finding, and facilitation of social interaction all contribute to the health-relevant themes of community, crime, and mode of transportation. In addition, the nearby natural environment, although often neglected, can serve as a remarkably effective resource. (*Am J Public Health.* 2003;93:1484–1489)

Stephen Kaplan, PhD, and Rachel Kaplan, PhD

URBAN ILLS ARE ALL TOO familiar, as is their capacity to undermine health. The results of numerous studies have increased our understanding of pieces of these problems but have been less effective in drawing attention to their interrelatedness. In this commentary, we suggest a conceptual framework that provides a broader view, embracing domains currently addressed by disparate fields of study. The Reasonable Person Model (RPM) bridges environmental factors and public health domains by focusing on meeting people's informational needs. RPM posits that people are more reasonable—cooperative, helpful, constructive—when the environment satisfies such needs.

Crime, lack of community, and dependence on motorized transportation serve as pertinent examples of rampant urban ills. They have a number of commonalties: clear links to public health, strong social components, and major ties to the built environment. Crime and its associated fears have pervasive and damaging influences on people's well-being and physical activity.[1] Fear of crime has also been an important factor in the flight from the cities and the resulting proliferation of sprawl. At the same time, the residential patterns that have mushroomed across the country in the last half century have reduced the sense of community, leading to social isolation, to "disconnection and fragmentation."[2(p13)] The same development patterns have vastly increased reliance on motor vehicles, leading to reduced physical activity and numerous other physical health problems.[3,4] These highly interrelated domains of urban and regional planning are thus intimately related to physical, mental, and social well-being.

Does reasonableness have anything do with these urban problems? Clearly, connecting with others requires reasonableness. Many exchanges among people do not fare well; incivility knows all too many forms. It is hardly a big leap to propose that unreasonableness undermines trust among people. However, the RPM addresses more than such social patterns. It also links human behavior with environmental factors. It is useful, then, to explore what qualities encourage people to be more reasonable with each other, with themselves, and with the places they depend upon.

THE REASONABLE PERSON MODEL

The RPM posits that people are more reasonable when their environment supports their basic informational needs.[5,6] To appreciate the importance of such needs, one must consider the role of information in human evolution. Lacking the speed and strength of other species, humans have depended on their capacity to seek, store, and share information.[7,8] However, at the same time information can be the bane of human functioning. An overwhelming amount of information, confusing information, and untrustworthy information can all readily threaten reasonableness.

We have organized people's core informational needs into 3 categories. The first, *exploration and understanding,* focuses on the acquisition and comprehension of information, both basic survival mechanisms for our species. The second, *meaningful action,* involves acting effectively based on the information one has. *Restoration,* the third category, deals with maintaining the capacity to focus on, select, and respond appropriately to the information in the environment. The 3 categories are highly interrelated. Meaningful action often requires understanding and invites exploration. Exploration can facilitate restoration. A more restored individual, in turn, can more effectively maneuver in complex settings.

Exploration and Understanding

Research on preference for outdoor environments, yielding results contrasting strongly with both theory and traditional practice at the time, led to us to propose these tandem concepts.[9] Across numerous studies using scenes of diverse outdoor environments, the single most important factor in predicting preferences turned out to be the content of the scene, and more particularly, the presence of natural elements. Beyond that, we found that 2 content-indepen-

dent predictors played important roles. First, the results showed preferences for scenes that were not confusing and where it seemed possible to wander without getting lost. This component came to be called *understanding*. Secondly, preferences were greatest if the scenes offered the possibility of discovery and learning, and especially the promise of more information as one imagined oneself walking further into the scene. This was called *exploration*.

Although originating from research on landscape preferences, these 2 themes—to make sense of and acquire new information—represent enduring inclinations in many domains. For an information-based animal, survival requires the mental capacity to recognize what is going on and to figure out what might happen next while there is still time to take appropriate action.[10] This requires a high priority on exploration to learn about the environment, while at the same time requiring that the animal not stray far so that it can understand the situation. As a result, humans are eager to explore but quick to retreat to the familiar, leading to a chronic restlessness characteristic of the species.

People want to make sense of what is going on and have a strong aversion to being confused. At the same time, they prefer and benefit from acquiring, at their own pace, information that is relevant to their concerns. Exploration provides a potent means of achieving understanding.

What properties of an environment can help support exploration and understanding?

1. The amount and rate of information should be manageable. Ideally, the individual has some role in deciding how much and how quickly to explore at any one time.[11]
2. Understanding requires building a cognitive map. This takes time and repeated exposures.[11]
3. In any environment, some things (like landmarks) are important; others (like advertising) may be less so. The bigger, brighter, and more distracting the less important aspects are, the harder it will be to build a mental map of the environment.[11]

Meaningful Action

The meaningful action component of RPM arose from the compelling findings about the harmful effects of feelings of helplessness,[12,13] along with the misguided notion that control offers an appropriate antidote (for detailed critiques, see references 14 and 15). Essentially, control is an unsatisfactory antidote for several reasons. (1) People only want control in certain circumstances; much more often they do not want the responsibility that comes with control, but rather want things to be *under control*. (2) Control is readily a zero-sum situation—when one party has more control, the other has less. (3) Control is often unrealistic; the forces of nature are typically not under human control. Human efforts to control nature have had many disastrous consequences. By contrast, participation is more realistic, less demanding, and far less likely to be harmful. People often want to be heard and to be a part of the process.

Helplessness has strong parallels to feeling "out of the loop," being disregarded, not mattering—all qualities that undermine reasonableness. By contrast, opportunities for exercising one's effectiveness serve as important examples of meaningful action. By achieving and enhancing competence, being useful to others, and gaining their respect,[16] one is less likely to feel helpless and worthless. Such motivations make good evolutionary sense. Being effective is adaptive; being known for one's effectiveness helps secure one's place in the group.

We propose participation as an important corrective to helplessness. Participation responds to people's strong motivation to be heard, to make a difference, to feel that they are needed.[17] It involves being part of the action, providing input or helping to do something that needs to be done. In the urban context especially, participation can link the individual to both the physical and the social environment,[18] ensuring that the person remains a functioning member of the local community. At the same time, activities that enhance a person's effectiveness can be health promoting in themselves and increase the likelihood of living in an environment that is compatible with the person's needs.[19] However, such occasions for participation can be meaningful even if they entail activities a person might not have chosen or find appealing. In his inaugural address in 1994, Detroit mayor Dennis Archer offered no promises, but rather challenged citizens to do their part—to "clean the rubbish from the storm sewer on YOUR street. Pick up the broken glass in YOUR alley. . . ."[20(pA7)] This call for participation was answered by a standing ovation.

Restoration

The third component of RPM deals with the decline in effectiveness and reasonableness because of mental fatigue. Deficits in understanding and exploration as well as the lack of opportunities for meaningful action can lead to such declines. However, even environments that are supportive in these respects can result in ineffectiveness and irritability if they contain large amounts of distracting information.

Although mental fatigue describes a very familiar phenomenon, it is a misleading label, as the mind per se is not fatigued. Rather it is a particular aspect of mental functioning, more appropriately described as the fatigue of directed attention.[21] Directed-attention fatigue makes it difficult to continue to pay attention to the many complex and competing demands in one's environment. In addition to irritability, characteristic symptoms of directed-attention fatigue are distractibility, impulsiveness, and impaired capacity to make and follow plans.

In the course of human evolution, directed attention was presumably needed far less than in modern times. A key function of directed attention is to pay attention to things that are important but not inherently interesting. For early humans, most of the things that were important—potential game, potential mates, potential dangers—were also innately interesting (just as they are to modern humans). However, for modern humans many things that are important are not particularly interesting, and many that are interesting (such as commercial advertising) are not important. Thus, directed attention is used far more extensively and is more likely to be fatigued in our contemporary world.

Many of the most effective settings for recovering from directed-attention fatigue involve the natural environment.[22] Such restorative environments are in short supply in many urban contexts. Unfortunately, environments that have the opposite effect are rampant. Transportation offers many examples of settings that can contribute to mental fatigue. Attentional resources are drained by the demands of traffic whizzing by or of navigating jammed highways lined with distracting billboards. Waiting endlessly for a bus in a place that is exposed to constant traffic as well as the elements can make mass transit no less demanding. The very notion of traffic-calming patterns acknowledges the widespread fatiguing influences of our daily means of locomotion. Road rage may be one of the more widely publicized symptoms of the resulting mental fatigue.

INFORMATION AND THE PHYSICAL ENVIRONMENT

A vast literature links the physical environment to community, crime, and transportation modes. In this section we look at some of the research findings in the context of the RPM. In particular, we take an informational perspective in examining the environmental factors to assess their impacts on human informational needs, and, in turn, on issues of health.

The arrangement of space conveys information that can make environments more interesting and attractive, facilitate way-findings, and enhance opportunities for exchange among individuals. In addition to environmental factors that are based on the way the space is organized, this section also highlights the particular role played by natural environments. Here it is the content—the trees, water, vegetation—that has strong health impacts.

Attractions

Gaining understanding generally requires repeated contact. In the neighborhood context, such repetition requires that people get out of their houses and move through their environment, ideally on foot. Exploration is encouraged when there are interesting, diverse, safe, and accessible routes and reasons for being outside. Booth et al.[23] found that among 2300 elderly persons in Australia, physical activity was significantly influenced by the availability of safe footpaths and access to facilities such as a park or recreation center. The importance of esthetic factors, including enjoyable scenery, in encouraging physical activity has been found in studies by King et al.[24] as well as studies reviewed by Humpel et al.[25] Attractive tree-lined sidewalks and functionally useful destinations (such as shops, parks, or a library) can thus contribute to health both by encouraging physical exercise and by fostering community as people become acquainted.

Benefits of having schools within walking distance have been documented in a variety of places. The Ontario Walkability Study,[26] for example, has shown that a vast majority of more than 6000 elementary school–aged children would prefer to walk or bicycle to school. One could easily have assumed that the comfort and convenience of being driven to school would have been their preference. The walk to school helps children understand their local environment. In a study of 6- and 7-year-old children in 57 schools in England, Lee[27] found that those who walked to school fared better than their peers who were bused, according a variety of "adjustment" measures including concentration, response to affection, and aggression. Lee interprets this finding in terms of the inability of the bused children to make a comfortable connection between home and school; rather, he suggests, they experience a "semi-permeable barrier" between these 2 environments.

As we have seen, an object, scene, or environment that fosters understanding and exploration is more likely to be preferred. Reactions to efforts by planners during the 1960s to achieve "slum clearance" provide useful evidence of such preferred environments. The intense and persisting grief Fried[28] described after the dislocation of Boston West End residents is clearly based on the loss of their social community; however, at the same time, their deep understanding of the physical structure of the community was also shattered. Similarly, Jacobs'[29] perceptive work provides vivid imagery of the attractions and opportunities for exploration offered by sidewalks, multiple alternative routes, and diversity of kinds and ages of structures.

People are attracted to environments that permit exploration and understanding and that offer nature with its restorative properties. Destinations that allow people to carry out meaningful actions, even purposes as simple as obtaining groceries or a library book, are also attractive. Thus, knowing what people prefer[17] is important to each aspect of RPM and more likely to provide settings that encourage active engagement.

Way-Finding

In the context of his incisive analysis of urban form, Lynch[30] wrote long ago of people's profound terror of being lost or disoriented. Such fears are by no means restricted to making one's way in cities. In 1981, Reizenstein and Vaitkus (cited in reference 31, p. 67) reported that when visitors and patients were asked about their sources of stress in the hospital environment, getting lost was highest on the list. Given the many other stresses associated with hospitals, this is all the more remarkable. Fear of being lost, in turn, can reduce the likelihood of exploration.

Exploration depends on way-finding. Way-finding can be assisted by signage and maps; it is also more directly enhanced by the way the environment is structured. Lynch[30] found that some cities were far more supportive of effective way-finding than others. He identified distinctive landmarks as an important factor in reducing the danger of disorientation. Diversity of land-use patterns as well as the styles and ages of buildings also support the ease of finding one's way. The sameness of many recently built housing developments and shopping strips fail to offer such guidance.

Way-finding can also be strongly impacted by street patterns. In many newer communities, cul-de-sacs reduce automobile traffic but at the cost of discouraging walking and bicycling and making way-finding more difficult. Neotraditional designs have thus returned to the grid pattern. A fascinating

synthesis of the 2 approaches, combining cul-de-sac and loop patterns at a neighborhood scale with a grid pattern at the community scale, offers the promise of supporting both local nonmotorized transportation and way-finding at the larger scale.[32]

Fellow Humans

The attractions offered by the environment and the environmental patterns that support needs for way-finding strongly impact how people relate to each other. The previously mentioned works by Jacobs[29] and Fried[28] provide classic examples of urban patterns that encourage social bonds. Fried interpreted the enduring grief experienced by the relocated residents of Boston's West End in terms of their loss of social networks that had been formed in a setting that fostered knowing each other. Such networks are less likely to develop where there are no sidewalks, where one sees one's neighborhood only as one drives through it to get to the nearest main road. Duany et al.[33] offer ample imagery of the social consequences that traditional subdivisions have for young people, elderly people, commuters, "soccer moms," poor people, and the surrounding cities. As Engwicht[34] shows, the simple act of reducing vehicular traffic opens the way to a multitude of environmental solutions for creating "vibrant communities."

Interestingly, the anonymity and lack of social bonds attributed to suburbia have also been negative forces in public housing. Pruitt-Igoe, a public housing project in St. Louis, served its tenants so badly that it was ultimately razed to the ground. The failure of this costly project can be understood in terms of the absence of "defensible space" and "semi-public space."[35,36] These concepts emphasize that community and trust require places where neighbors can meet to become acquainted and where surveillance is easily possible. In apartments for elderly people, for example, the area where residents get their mail can serve these functions. Front porches, a theme that has been revived by new urbanist designers, similarly offer a transitional space that allows information to be exchanged and encourages people to get to know each other.[37] Oldernburg's[38] concept of "third places," such as pubs, drugstores, and cafés, provides a similar example of the way a setting can help create familiarity and hence community.

Special Role of Nature

The powerful effects of the natural environment are striking because they apply so broadly yet do not require extensive exposure in terms of either time or space. Even the minimal encounters with nature afforded by the view from the window have been shown to be related to health benefits in the context of hospitals[39,40] and prisons,[41,42] as well as the workplace[43] and home environment.[44] In a large-scale, 5-year follow-up cohort study of older people, perceived access to walkable green space was found to predict longevity, even after controlling for age, socioeconomic status, gender, and marital status.[45] Frumkin[46] discusses findings of numerous other studies that document the health benefits of the nearby natural environment.

The work of Kuo and Sullivan has been particularly important in showing the dramatic role played by the availability of vegetation in the context of public housing. In a series of studies they have shown the presence of nearby natural areas to be related to reduced crime, aggression, and violence[47,48] as well as increased civility and neighborliness.[49] As these researchers indicate, the results strongly support the restoration portion of RPM[21]; their careful statistical analyses showed the effect to be attributable to the greater attentional capacity of residents in apartments with natural areas nearby.

Strong preference for nearby natural settings is evidenced not only in many empirical studies but by countless ballot outcomes showing citizens' willingness to be taxed for urban green spaces and for the preservation of nearby farms and forests.[50] Municipalities that offer opportunities for public participation often hear that citizens desire more natural areas and trails. Having natural areas nearby can provide incentives for walking and bicycling; increased pedestrian activity can enhance the likelihood that people will become familiar with each other.[51] Participation in local nature activities can increase the sense of pride in one's community[52] and strengthen urban neighborhoods.[53]

Natural areas have the potential to be both attractive and restorative. They encourage outdoor activities and have the potential for making one's neighbors more reasonable and one's community safer. They can thus enhance exploration and understanding as well as facilitating meaningful action in the form of community participation.

SMALL THINGS THAT MAKE BIG DIFFERENCES

Recognition of the multifaceted and extensive connections between the public health domain and issues related to land use and planning has been growing,[2,54] with this issue of the *American Journal of Public Health* taking a further step in that direction. However, identifying these connections may not be sufficient for finding workable solutions. We offer the RPM as a way to provide general principles for identifying needed changes by addressing both environmental factors and broad health issues in the context of human informational needs. Although many studies support the appropriateness of such an approach, many opportunities for directly testing this model remain to be explored.

In some ways, what we are proposing may be seen as a radical change; however, the factors we have identified can be implemented in many small and inexpensive steps. Such changes involve making the environment more understandable, creating interesting but reassuring opportunities for exploration, providing settings that offer restorative experiences, and incorporating processes that include people in decisionmaking.

Natural environments can bring a remarkable range of benefits. Preservation and enhancement of small pieces of nature in the urban environment can be achieved at little cost. Incorporating volunteers in these efforts, as has been the case with respect to urban tree planting and natural area maintenance, does much more than reduce the cost. It provides health benefits and opportunities for

meaningful action for the participants and is a source of pride to their community.

The economic perspective, currently dominant in planning, views many environmental changes in terms of amenities, failing to recognize their health implications and significance in terms of less tangible yet far more vital consequences. RPM shifts the emphasis from economics to a concern for meeting human needs. Such an approach can be implemented through numerous small changes that can make big differences. Such changes can offer even greater benefits when they are made by, and not for, communities. Through their participation, community members gain meaning while contributing to their own health and that of their community. ■

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References

1. Baker EA, Brennan LK, Brownson R, Houseman RA. Measuring the determinants of physical activity in the community: current and future directions. *Res Q Exerc Sport.* 2000;71: 146–158.

2. Duhl LJ, Sanchez AK. *Healthy Cities and the City Planning Process: A Background Document on Links between Health and Urban Planning.* Copenhagen, Denmark: World Health Organization European Regional Office; 1999. Publication EUR/ICP/CHDV 03 04. 03. Available at: http://www.who.dk/document/e67843.pdf. Accessed November 8, 2002.

3. Jackson RJ, Kochtitzky C. *Creating a Healthy Environment: The Impact of the Built Environment on Public Health.* Washington, DC: Sprawl Watch Clearinghouse Monograph Series; 2001. Available at: http://www.sprawlwatch.org. Accessed January 10, 2002.

4. Rütten A, Abel T, Kannas L, et al. Self reported physical activity, public health, and perceived environment: results from a comparative European study. *J Epidemiol Community Health.* 2001;55:139–146.

5. Kaplan S. Human nature and environmentally responsible behavior. *J Soc Issues.* 2000;56:491–508.

6. Kaplan R. The social values of forests and trees in urbanized societies. In: Konijnendijk CC, Koch NE, Hoyer KH, Schipperijn J, eds. *Forestry Serving Urbanised Societies.* (Proceedings of the IUFRO European Regional Conference, 27–30 August 2002, Copenhagen). Hoersholm, Denmark: Skov & Landskab. In press.

7. Laughlin WS. Hunting: an integrating biobehavior system and its evolutionary importance. In: Lee RB, DeVore I, eds. *Man the Hunter.* Chicago: Aldine; 1968:304–320.

8. Kaplan S. Cognitive maps in perception and thought. In: Downs RM, Stea D, eds. *Image and Environment.* Chicago: Aldine; 1973:63–78.

9. Kaplan R, Kaplan S. *The Experience of Nature: A Psychological Perspective.* New York: Cambridge University Press; 1989.

10. Kaplan S. Environmental preference in a knowledge-seeking knowledge-using organism. In: Barkow JH, Cosmides L, Tooby J, eds. *The Adapted Mind.* New York: Oxford University Press; 1992:535–552.

11. Kaplan S, Kaplan R. *Cognition and Environment: Functioning in an Uncertain World.* New York: Praeger; 1982.

12. Peterson C, Maier SF, Seligman MEP. *Learned Helplessness: A Theory for the Age of Personal Control.* New York: Oxford University Press; 1993.

13. Seligman MEP. *Helplessness: On Depression, Development, and Death.* San Francisco: WH Freeman & Co; 1975.

14. Antonovsky A. *Unraveling the Mystery of Health: How People Manage Stress and Stay Well.* London: Jossey-Bass Publishers; 1988.

15. Little BR. Personality and the environment. In: Stokols D, Altman I, eds. *Handbook of Environmental Psychology.* New York: John Wiley & Sons; 1987: 205–244.

16. Goldschmidt W. *The Human Career: The Self in the Symbolic World.* Cambridge, Mass: Blackwell; 1990.

17. Kaplan R, Kaplan S, Ryan RL. *With People in Mind: Design and Management of Everyday Nature.* Washington, DC: Island Press; 1998.

18. Ryan RL, Kaplan R, Grese RE. Predicting volunteer commitment in environmental stewardship programs. *J Environ Planning Management.* 2001;44: 629–648.

19. *Community Participation in Local Health and Sustainable Development: A Working Document on Approaches and Techniques.* Copenhagen, Denmark: World Health Organization European Regional Office; 1999. Publication EUR/ICP/POLC 06 03 05D. European Sustainable Development and Health Series, No. 4. Available at: http://www.dhs.vic.gov.au/phd/localgov/downloads/who_book4.pdf. Accessed December 2, 2002.

20. Hoogterp E. Call to action: inaugural speech urges Detroiters to reclaim neighborhoods. *Ann Arbor News.* January 4, 1994:A7.

21. Kaplan S. The restorative benefits of nature: toward an integrative framework. *J Environ Psychol.* 1995;15: 169–182.

22. Kaplan S. Some hidden benefits of the urban forest. In: Konijnendijk CC, Koch NE, Hoyer KH, Schipperijn J, eds. *Forestry Serving Urbanised Societies.* (Proceedings of the IUFRO European Regional Conference, 27–30 August 2002, Copenhagen). Hoersholm, Denmark: Skov & Landskab. In press.

23. Booth ML, Owen N, Bauman A, Clavisi O, Leslie E. Social-cognitive and perceived environment influences associated with physical activity in older Australians. *Prev Med.* 2000;31: 15–22.

24. King AC, Castro C, Wilcox S, Eyler AA, Sallis JF, Brownson RC. Personal and environmental factors associated with physical inactivity among different racial-ethnic groups of US middle-aged and older-aged women. *Health Psychol.* 2000;19: 354–364.

25. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med.* 2002;22: 188–199.

26. Ontario Walkability Study. *Trip to School: Children's Experiences and Aspirations.* Ottawa: Ontario Ministry of the Environment; 2001. Available at: http://www.greenestcity.org/asrts/Walkability%20Study%20Report.pdf. Accessed July 22, 2002.

27. Lee TR. On the relation between the school journey and social and emotional adjustment in rural infant children. *Br J Educ Psychol.* 1957;27: 101–114.

28. Fried M. Grieving for a lost home. In: Duhl LJ, ed. *The Urban Condition.* New York: Basic Books; 1963:151–171.

29. Jacobs J. *The Death and Life of Great American Cities.* New York: Random House; 1961.

30. Lynch K. *The Image of the City.* Cambridge, Mass: MIT Press; 1960.

31. Carpman JR, Grant MA. *Design That Cares: Planning Health Facilities for Patients and Visitors.* 2nd ed. Chicago: American Hospital Publishing; 1993.

32. Tasker-Brown J, Pogharian S. *Learning From Suburbia: Residential Street Pattern Design.* Ottawa: Canada Mortgage & Housing Corp.; 2000.

33. Duany A, Plater-Zyberk E, Speck J. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream.* New York: North Point Press; 2000.

34. Engwicht E. *Street Reclaiming: Creating Livable Streets and Vibrant Communities.* Gabriola Island, BC, Canada: New Society Publishers; 1999.

35. Yancy WL. Architecture, interaction and social control. *Environment Behav.* 1971;3:3–21.

36. Newman O. *Defensible Space: Crime Prevention Through Urban Design.* New York: Macmillan Publishing Co; 1972.

37. Cooper CC. *Easter Hill Village: Some Social Implications of Design.* New York: Free Press; 1975.

38. Oldenburg R. *The Great Good Place: Cafes, Coffee Shops, Community Centers, Beauty Parlors, General Stores, Bars, Hangouts and How They Get You Through the Day.* New York: Paragon House; 1989.

39. Ulrich RS. View through a window may influence recovery from surgery. *Science.* 1984;224:420–421.

40. Verderber S. Dimensions of person-window transactions in the hospital environment. *Environment Behav.* 1986;18: 450–466.

41. Moore EO. A prison environment's

effect on health care service demands. *J Environ Systems.* 1981;11:17–34.

42. West MJ. *Landscape Views and Stress Responses in the Prison Environment* [unpublished master's thesis]. Seattle, Wash: University of Washington; 1986.

43. Kaplan R. The role of nature in the context of the workplace. *Landscape Urban Plann.* 1993;26:193–201.

44. Kaplan R. The nature of the view from home: psychological benefits. *Environment Behav.* 2001;33;507–542.

45. Takano T, Nakamura K, Watanabe M. Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces. *J Epidemiol Community Health.* 2002;56:913–918.

46. Frumkin H. Beyond toxicity: human health and the natural environment. *Am J Prev Med.* 2001;20: 234–240.

47. Kuo FE, Sullivan WC. Environment and crime in the inner city: does vegetation reduce crime? *Environment Behav.* 2001;33:343–367.

48. Kuo FE, Sullivan WC. Aggression and violence in the inner city: impacts of environment via mental fatigue. *Environment Behav.* 2001;33:543–571.

49. Kuo FE, Sullivan WC, Coley RL, Brunson L. Fertile ground for community: inner-city neighborhood common spaces. *Am J Community Psychol.* 1998; 26:825–851.

50. Land Vote 2002: Americans invest in parks and open space. Available at http://www.landvote.org. Accessed July 18, 2003.

51. Kim J. *Sense of Community in Neotraditional and Conventional Suburban Developments: A Comparative Case Study of Kentlands and Orchard Village* [dissertation]. Ann Arbor, Mich: University of Michigan; 2001.

52. Austin ME. Partnership opportunities in neighborhood tree planting initiatives: building from local knowledge. *J Arboriculture.* 2002;28: 178–186.

53. Inerfeld RB, Blom BB. A new tool for strengthening urban neighborhoods. *J Affordable Housing.* 2002;11: 128–134.

54. Frank LD, Engelke PO. The built environment and human activity patterns: exploring the impacts of urban form on public health. *J Plann Literature.* 2001;16;202–218.

Indoor Environments and Health: Moving Into the 21st Century

The quality of our indoor environments affects well-being and productivity, and risks for diverse diseases are increased by indoor air pollutants, surface contamination with toxins and microbes, and contact among people at home, at work, in transportation, and in many other public and private places.

We offer an overview of nearly a century of research directed at understanding indoor environments and health, consider current research needs, and set out policy matters that need to be addressed if we are to have the healthiest possible built environments. The policy context for built environments extends beyond health considerations to include energy use for air-conditioning, selection of materials for sustainability, and design for safety, security, and productivity. (*Am J Public Health.* 2003;93:1489–1493)

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THE VERY PUBLICATION OF AN issue of the *American Journal of Public Health* on "the built environment" signals a timely recognition of the relevance to health and well-being of the indoor environments where people spend most of their time. Even in temperate climates, including that of the United States, people spend most of their time indoors: at home, at work, in transportation, and in many other public and private places. The quality of these environments affects well-being and productivity, and risks for diverse diseases are increased by indoor air pollutants, surface contamination with toxins and microbes, and contact among people in these places. These are not new problems; they have been the focus of research and of control efforts for decades. The emphasis on the built environment indicates a shift toward a more holistic approach to indoor environments and the public's health, a shift consistent with the broadening recognition of the multiple levels of environmental factors, from the personal to the global, that determine an individual's health.

Here we offer a perspective on this shifting emphasis that has led to a move from consideration of specific problems within indoor environments, such as radon and lung cancer, to a broader view that involves a greater emphasis on prevention. We recognize that some of the specific problems of indoor environments remain quite relevant and are a current focus for research, public concern, policy development, and even litigation. The health consequences of dampness and mold are a current example, and there are always emerging issues such as phthalates, organophosphates, and pyrethroid pesticides. Our intent is not to cover these individual topics, which have been reviewed in depth elsewhere.[1] Rather, we offer an overview of nearly a century of research directed at understanding indoor environments and health, consider current research needs, and set out policy matters that need to be addressed if we are to have the healthiest possible built environments. We note that the policy context for built environments extends beyond health considerations to include energy use for air-conditioning, selection of materials for sustainability, and design for safety, security, and productivity.

HISTORICAL PERSPECTIVE: PROBLEMS RECOGNIZED

Theories have long been advanced with regard to building ventilation and health. At the start of the last century, ventilation was viewed as healthy and as decreasing risks for infection.[2] The important early work of Constantin Yaglou, reported in the 1930s, established a paradigm for using ventilation as a means of achieving thermal and odor comfort in the built envi-

ronment.[3,4] For the next 50 years, dilution of human odors motivated the mechanical design of buildings and guided the use of often large heating, ventilating, and air-conditioning systems. In the latter part of the 20th century, as health and comfort problems associated with buildings became apparent, Ole Fanger and others pointed out that office equipment, materials, and even heating, ventilating, and air-conditioning systems themselves add to the odor and contaminant load of buildings and cause discomfort to occupants.[5]

In the 21st century, we have returned to concern for airborne spread of infection. With new analytical tools that can isolate specific strains of viruses from a room air sample or a specimen of nasal mucus, we can further advance our understanding of the role of ventilation and health and the potential for interrupting disease transmission in indoor environments. Perhaps the most dramatic demonstration of the need for new information on this issue was the dissemination of anthrax spores in postal facilities during the 2001 bioterrorism episode.

The more contemporary recognition of the relevance of the built environment to health came when measurements of levels of specific pollutants were first made in indoor air and the major contributions of indoor exposures to total personal exposures to air pollution were recognized. This recognition was broadened by such dramatic problems as mobile homes that could not be occupied because of extremely high levels of formaldehyde from building materials, the finding of homes with radon levels as high as those in underground uranium mines, and the appearance of a new clinical syndrome, often referred to as "sick-building syndrome," that was linked to the building environment.

Some of the first measurements of indoor air pollutants were made in the 1960s.[6] In 1965, for example, Biersteker and colleagues[7] measured nitrogen dioxide levels in Dutch homes, finding that this outdoor air pollutant was present at high levels in homes with gas-fired combustion devices. Some of the initial measurements of tobacco smoke components were made in the 1970s,[8,9] and asbestos fibers were found in indoor air in public buildings and schools in the late 1970s and early 1980s.[10] Radon had been measured in indoor air as early as the 1950s but gained prominence as large numbers of measurements were taken in the 1970s and 1980s and homes were found with dramatically high concentrations. The problem of lead paint and lead-contaminated surface dust in inner-city homes was recognized in the 1950s and 1960s.[11]

The health- and risk-relevant concept of total personal exposure to pollutants was introduced in the 1970s and provided a framework for integrating and interpreting pollutant measurements taken indoors and outdoors.[12] In the microenvironmental model, total personal exposure to a contaminant is the time-weighted average of pollutant concentrations in the various "microenvironments" where time is spent. In the 1980s, investigators involved with the US Environmental Protection Agency's Total Exposure Assessment Methodology Study used this model to comprehensively assess the contributions of indoor and outdoor exposures to total personal exposures to selected volatile organic chemicals, such as benzene.[13] This study yielded the then startling conclusion that indoor pollution sources are generally a far more significant contributor to total personal exposures to toxic volatile organic compounds than are releases by some industrial sources into outdoor air. The Harvard Six-Cities Study, recognized as a landmark investigation of outdoor air pollution, also proved to be an invaluable research platform for understanding residential indoor air pollution and its strong contributions to total personal exposures to a number of pollutants, including particles, sulfates, and nitrogen oxides.[14–16]

SOME PROBLEMS SOLVED

The measurement of these and other indoor air pollutants was quickly followed by research directed at their health effects. Epidemiological studies with cross-sectional and cohort designs focused on the risks of exposures at home, and a more limited number considered workplace exposures, particularly to tobacco smoke. Case–control studies and a few cohort studies of secondhand smoke exposure and lung cancer risks among nonsmokers were carried out. The risks of cancer associated with asbestos and radon were estimated through extrapolation of risks from studies of workers,[10,17] but ecological and case–control studies of indoor radon and lung cancer in the general population were also initiated as early as the late 1970s.[18]

Studies of infants and children addressed adverse respiratory effects of nitrogen dioxide, secondhand tobacco smoke exposure, and biological agents, particularly indoor allergens. The earliest of these studies date to the late 1960s, and research conducted over the ensuing decades has provided convincing evidence for adverse effects of secondhand smoke, radon, and some biological agents. The evidence remains mixed in the case of certain other indoor pollutants, such as volatile organic compounds and nitrogen dioxide.

Research on the adverse effects of involuntary smoking on the respiratory health of children began in the late 1960s; the first studies on involuntary smoking and lung cancer were published in 1981.[19,20] The possibility of preventing exposure through elimination of indoor smoking was always clear, and as the epidemiological evidence mounted, increasing numbers of municipalities and states implemented policies designed to reduce or ban smoking in public places and workplaces. By 1986, the US surgeon general and the National Research Council had concluded that involuntary smoking causes lung cancer and has adverse effects on the respiratory health of children[21,22]; the list continues to expand, now including coronary heart disease as well.

With these causal conclusions, the debate over tobacco use shifted from the rights of an individual to use a product to the right of the public to breathe clean indoor air. Increasingly stringent control measures had broad effects; the majority of workplaces in the United States are now smoke-free, as are almost all commercial air flights, and levels of cotinine, the tobacco smoke biomarker, have declined sharply in the United States in recent years.[23] Reducing involuntary smoking in homes is a remaining challenge, one that can be addressed prima-

rily through education. Unfortunately, passive smoking remains a worldwide problem, particularly for women and children.[24]

Indoor radon, labeled "the colorless, odorless killer," gained notoriety in the United States in the early 1980s, after media reports of a Pennsylvania home with such high levels that the nuclear power plant worker who lived there triggered the radiation monitoring system at the plant when he arrived at work. In the subsequent 20 years, we have gained an increasingly complete picture of the risks posed by indoor radon exposure.[25] A pooled analysis of data from 11 cohort studies of underground miners was carried out to estimate the risks of indoor radon, with complementary evidence gained from case–control studies of lung cancer in the general population.[18,26] Elegant experimental models, involving irradiation of single cells with single alpha particles, provide results consistent with a linear nonthreshold relationship between typical concentrations of indoor radon and lung cancer risk.[27,28] The source of most indoor radon, soil gas, is well characterized, and radon concentrations can be measured cheaply and with reasonable accuracy.

In spite of the abundant scientific evidence supporting strategies for radon control, including measuring and mitigating homes with high levels of radon and building radon-resistant homes, the voluntary initiatives of the Environmental Protection Agency have met with limited acceptance by the public.[29–31] According to agency reports, 18 million US homes have been tested and 50 000 homes mitigated since the mid-1980s.[32] The voluntary approach is strengthened in instances in which radon testing is a standard requirement in purchase and sales agreements for homes.

Asbestos, another inhaled carcinogen, was widely used in the United States through the 1970s as an insulating material in public and commercial buildings; it has also been used to insulate piping in residences, and there is a potential for exposures in homes if the asbestos-containing material is friable. Concern about asbestos indoors first followed the recognition that insulating materials in many schools contained asbestos and some of the first measurements in schools indicated the possibility of unsafe levels in the air. Under the Asbestos Hazard Emergency Response Act,[33] school systems had the option of either removing the asbestos or maintaining it in place. Initially, asbestos-containing material was removed from many schools, at substantial expense; however, this approach was reevaluated as further measurements were obtained and options for managing asbestos-containing materials in commercial buildings were considered. A risk assessment carried out by the Health Effects Institute proved pivotal in pushing control toward in-place management.[10] Concerns about indoor asbestos may arise again after it becomes widely known that tremolite asbestos fibers are contained in Zonolite insulation, which is used in millions of homes, businesses, and schools.[34]

Nitrogen dioxide, one of the first pollutants measured indoors, can adversely affect lung function at high concentrations; thus, when it was found to be emitted by such ubiquitous appliances as gas stoves, epidemiological studies were initiated on its effects on the respiratory health of children and adults.[35,36] The findings of these studies have not provided consistent evidence for adverse effects of nitrogen dioxide, and levels in homes have declined as stoves with electronic ignitions have replaced older stoves with gas pilot lights and cooking patterns in the United States have moved toward increasing use of microwaves and less cooking in general. Some higher level exposures persist, however. Gas stoves are still used for supplemental heating, particularly among individuals who reside in public housing units, which are often not submetered for gas use. Also, quite high levels of nitrogen dioxide have been measured in poorly ventilated indoor ice rinks resurfaced with machines powered by gasoline or diesel engines.[37]

Biological agents have proved challenging; they are myriad and cause disease through both infectious and noninfectious mechanisms. Nonetheless, we have sufficient evidence to prevent the diseases caused by certain specific agents. Transmission of *Legionella* species through inadequately maintained cooling equipment for heating, ventilating, and air-conditioning systems and building water systems is well recognized, and building-related[38] (as well as cruise ship) epidemics of *Legionella* infection can be avoided through proper cleaning and maintenance. Numerous indoor allergens have been measured, and some have been linked to exacerbation and possibly causation of allergic diseases, including asthma. Control measures can reduce exposures to certain of these agents (e.g., cockroach and mite antigens), but substantial health benefits have not been readily shown, in part because of the difficulties involved in maintaining reduced levels.[39]

APPROACHING THE PROBLEMS REMAINING TO BE SOLVED

The single most pervasive and harmful indoor air problem worldwide is the oldest: smoke from fires. Domestic cooking and heating with biomass fuels of wood, crop residues, dried animal dung, or charcoal and coal can produce substantial indoor concentrations of particles, carbon monoxide, and polycyclic aromatic hydrocarbons. According to the World Health Organization's 2002 report[40] on global burden of disease, the almost daily exposure to smoke among billions of people, primarily women and young children, is the 8th leading cause of disability-adjusted life years lost, accounting for nearly 3% of the world's total burden of disease.

For more than 2 decades, we have known that improving stove efficiency, providing working flue vents, and improving fuel quality (e.g., switching from biomass fuels to propane or liquefied petroleum gas) could dramatically reduce acute respiratory infections, chronic lung and heart disease, and blindness. China has introduced stove improvement programs on a massive scale, and these programs have been successful. Land reclamation programs in India have demonstrated that investments in biogas digesters and liquefied natural gas cook stoves will be made as economic prosperity increases. However, the prospects for improvements among individuals trapped in third world poverty are dim, in that the costs of less

polluting cooking and heating fuels or stoves are prohibitive.

Many of the recognized indoor air quality problems facing developed countries are avoidable. If achieving a healthy indoor environment were a specific design criterion for buildings, many of the recurring problems of mold, pest allergens, radon, organic compounds, nitrogen dioxide, and carbon monoxide could be controlled. Indoor tobacco smoking has been reduced, but achieving effective control in homes remains a challenge; educational strategies are needed, particularly for protecting those at greatest risk, such as infants and children with asthma. Attention should be focused on particularly critical building environments; because children spend a substantial amount of their time in them, schools are one obvious example.

One lesson that has been learned repeatedly is the need to approach the built environment with multidisciplinary teams, whether the focus is on research, design and problem solving, or planning for the future. There is far too much isolation of the professionals involved—including public health and medical scientists and researchers, architects, engineers, city planners, and building managers—and there is insufficient engagement with the needs of the population itself.

We have convened interdisciplinary meetings to address indoor air quality issues and have been impressed with the immediate recognition among the participants of the necessity for interdisciplinary interactions on such issues as sick-building syndrome, air cleaning, and the level of optimal humidity.[41,42] Over the past several decades, the professional occupation category of indoor air quality specialist has developed, and there are private firms providing indoor air quality services. Since 1978, the triennial indoor air conferences held by the International Academy of Indoor Air Sciences have offered an international venue for scientific exchange among the many disciplinary experts concerned with the built environment. Some of the critical topics have been addressed by committees of the National Research Council, the Institute of Medicine, and other organizations.[18,43,44]

With an ever-growing research base available, the scientific evidence on indoor air should inform the process of designing and maintaining buildings. All too often, well-intended inclusion of indoor air quality as a consideration is reduced to a simple checklist of general items to be avoided and to compliance with ventilation codes. This approach reflects a "dumbing down" of the complex ways in which humans interact with the environment. A more comprehensive rethinking is needed on the physiological, sociological, ergonomic, and psychological characteristics of the built environment that affect health and well-being.

Many building codes and design criteria are not soundly based in regard to their consequences for human performance (e.g., lighting requirements). Ventilation requirements for buildings have been assessed, along with those for temperature and humidity, more on the basis of meeting comfort criteria than with an orientation toward health or even productivity. Remarkably, there has never been a comprehensive study on the role of ventilation and health and comfort in homes. The current guidelines of the American Society of Heating, Refrigerating, and Air Conditioning Engineers[45] recommend a minimum air exchange rate of 35% per hour for homes. However, associations of homebuilders have resisted attempts to specify mechanical means to achieve this recommended exchange rate or to institute higher exchange rates for homes.

New issues related to the built environment will inevitably emerge. On the current short list of chemicals likely to be of concern are several synthetic organic compounds: polychlorinated biphenyls in building materials; phthalates in polyvinyl chloride materials used in flooring, wall coverings, cables, foam, and other products of which plastic is a component; polybrominated diphenyl esters, which are fire retardants used in many products, including computers; pesticide residues, including the recently introduced family of pyrethroids; and cleaning agents such as those with phenol, among other potentially sensitizing compounds.

The current concern about intentionally introduced viruses and other infectious organisms as acts of bioterrorism will advance research on the role of building ventilation and air cleaning in the transmission of pathogenic organisms. As more multidisciplinary research on health and buildings is carried out, the effects of space characteristics, materials, lighting, and air quality on stress and performance should become better understood. Studies of workforce health complaints related to building environments have been methodologically complicated by the nonspecificity of most complaints, and it is often impossible to separate causal effects of engineering and design factors from job stress, personal stress, and the perception of unsatisfactory indoor environmental conditions. A recently published research agenda for indoor environments and worker health emphasized building-related asthma and allergic diseases in addition to communicable respiratory infections and nonspecific building-related symptoms.[46]

Research continues, but in the case of some problems the public, Congress, and lawyers will not await more certainty from scientific investigations. For example, state and federal legislation on toxic mold has been proposed. Many individuals, building owners, and insurance companies have been affected by the consequences of water damage and molds, and there is uncertainty as to health risks and control approaches. Effective policy approaches are urgently needed for the problem of indoor molds and moisture. The current situation is reminiscent of the past tumultuous debates and litigation around asbestos in buildings. In the 1980s and early 1990s, expensive removal of asbestos-containing material was the first course of action regardless of whether the presence of that material actually exposed occupants to asbestos fibers. Currently, insurance companies are attempting to write policies excluding mold liability or simply refusing to provide coverage in states where mold claims are widespread. This situation needs resolution through science-based policies and perhaps legislation, but the needed research has yet to be carried out.

We are hopeful that this issue of the *Journal* will contribute to the continuing development of the research and policy agenda for improving the

built environment. Unfortunately, this topic has received inadequate emphasis, particularly in comparison with the substantial resources directed toward outdoor air pollution. ■

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References

1. Spengler JD, Samet JM, McCarthy JF, eds. *Indoor Air Quality Handbook.* New York, NY: McGraw-Hill Book Co; 2000.

2. Addington DM. The history and future of ventilation. In: Spengler JD, Samet JM, McCarthy JF, eds. *Indoor Air Quality Handbook.* New York, NY: McGraw-Hill Book Co; 2000:2.1–2.16.

3. Yaglou CP, Riley EC, Coggins DI. Ventilation requirements: heating, piping and air conditioning. *ASHRAE J.* 1936;42:65–76.

4. Yaglou CP, Witheridge WN. Ventilation requirements, part 2: heating, piping and air conditioning. *ASHRAE J.* 1937;43:1–4.

5. Fanger PO, Valbjorn O. *Indoor Climate: Effects on Human Comfort, Performance, and Health in Residential, Commercial, and Light-Industry Buildings.* Copenhagen, Denmark: Danish Building Research Institute; 1979.

6. National Research Council, Committee on Indoor Pollutants. *Indoor Pollutants.* Washington, DC: National Academy Press; 1981.

7. Biersteker K, de Graaf H, Nass CAG. Indoor air pollution in Rotterdam homes. *Int J Air Water Pollut.* 1965;9: 343–350.

8. Hinds WC, First MW. Concentrations of nicotine and tobacco smoke in public places. *N Engl J Med.* 1975;292: 844–845.

9. Repace JL, Lowrey AH. Indoor air pollution, tobacco smoke, and public health. *Science.* 1980;208:464–472.

10. Health Effects Institute, Asbestos Research Committee, Literature Review Panel. *Asbestos in Public and Commercial Buildings: A Literature Review and a Synthesis of Current Knowledge.* Cambridge, Mass: Health Effects Institute; 1991.

11. Markowitz G, Rosner D. *Denial and Deceit: The Deadly Politics of Industrial Pollution.* Berkeley, Calif: University of California Press; 2002.

12. National Research Council, Committee on Advances in Assessing Human Exposure to Airborne Pollutants. *Human Exposure Assessment for Airborne Pollutants: Advances and Opportunities.* Washington, DC: National Academy Press; 1991.

13. Wallace LR. *The Total Exposure Assessment Methodology (TEAM) Study: Summary and Analysis.* Washington, DC: Office of Research and Development, US Environmental Protection Agency; 1987.

14. Speizer FE, Ferris BG Jr, Bishop YM, Spengler JD. Respiratory disease rates and pulmonary function in children associated with NO2 exposure. *Am Rev Respir Dis.* 1980;121:3–10.

15. Dockery DW, Pope CA III, Xu X, et al. An association between air pollution and mortality in six U.S. cities. *N Engl J Med.* 1993;329:1753–1759.

16. Ware JH, Dockery DW, Spiro A III. Passive smoking, gas cooking, and respiratory health of children living in six cities. *Am Rev Respir Dis.* 1984;129: 366–374.

17. National Research Council, Committee on the Biological Effects of Ionizing Radiation. *Health Risks of Radon and Other Internally Deposited Alpha-Emitters: BEIR IV.* Washington, DC: National Academy Press; 1988.

18. National Research Council, Committee on Health Risks of Exposure to Radon, Board on Radiation Effects Research, Commission on Life Sciences. *Health Effects of Exposure to Radon (BEIR VI).* Washington, DC: National Academy Press; 1998.

19. Hirayama T. Nonsmoking wives of heavy smokers have a higher risk of lung cancer: a study from Japan. *BMJ.* 1981;282:183–185.

20. Trichopoulos D, Kalandidi A, Sparros L, MacMahon B. Lung cancer and passive smoking. *Int J Cancer.* 1981;27:1–4.

21. *The Health Consequences of Involuntary Smoking: A Report of the Surgeon General.* Washington, DC: US Dept of Health and Human Services; 1986. DHHS publication CDC 87-8398.

22. National Research Council, Committee on Passive Smoking. *Environmental Tobacco Smoke: Measuring Exposures and Assessing Health Effects.* Washington, DC: National Academy Press; 1986.

23. *Second National Report on Human Exposure to Environmental Chemicals. Results.* Atlanta, Ga: Centers for Disease Control and Prevention; 2003. NECH Pub No. 02–0716.

24. Samet JM, Yang G. Passive smoking, women and children. In: Samet JM, Yoon S-Y, eds. *Women and the Tobacco Epidemic: Challenges for the 21st Century.* Geneva, Switzerland: World Health Organization; 2001:17–45.

25. Samet JM, Eradze GR. Radon and lung cancer risk: taking stock at the millennium. *Environ Health Perspect.* 2000; 108(suppl 4):635–641.

26. Lubin JH, Boice JD Jr, Edling C, et al. *Radon and Lung Cancer Risk: A Joint Analysis of 11 Underground Miners Studies.* Bethesda, Md: National Institutes of Health; 1994.

27. Zhou H, Randers-Pehrson G, Waldren CA, Vannais D, Hall EJ, Hei TK. Induction of a bystander mutagenic effect of alpha particles in mammalian cells. *Proc Natl Acad Sci USA.* 2000;97: 2099–2104.

28. Zhou H, Suzuki M, Randers-Pehrson G, et al. Radiation risk to low fluencies of alpha particles may be greater than we thought. *Proc Natl Acad Sci USA.* 2001;98:14410–14415.

29. *A Citizen's Guide to Radon: The Guide to Protecting Yourself and Your Family From Radon.* 2nd ed. Washington, DC: US Environmental Protection Agency; 1992.

30. *A Citizen's Guide to Radon: What It Is and What to Do About It.* 2nd ed. Washington, DC: US Environmental Protection Agency; 1992.

31. Cole LA. *Elements of Risk: The Politics of Radon.* Washington, DC: American Association for the Advancement of Science; 1993.

32. Gregory B, Jalbert PP. *National Radon Results: 1985 to 1999.* Washington, DC: US Environmental Protection Agency; 2001.

33. Asbestos Hazard Emergency Response Act, HR 5073 (1986).

34. Bowker M. *Fatal Deception: The Untold Story of Asbestos. Why It Is Still Legal and Still Killing Us.* Emmaus, Pa: Rodale; 2003.

35. Samet JM, Basu R. A review of the epidemiological evidence on health effects of nitrogen dioxide exposure from gas stoves. *J Environ Med.* 1999;1: 173–187.

36. Samet JM, Utell MJ. The risk of nitrogen dioxide: what have we learned from epidemiological and clinical studies? *Toxicol Ind Health.* 1990;6: 247–262.

37. Brauer M, Spengler JD. Nitrogen dioxide exposures inside ice skating rinks. *Am J Public Health.* 1994;84: 429–433.

38. Barry BE. Legionella. In: Spengler JD, Samet JM, McCarthy JF, eds. *Indoor Air Quality Handbook.* New York, NY: McGraw-Hill Book Co; 2000: 48.1–48.15.

39. Burge HA. An update on pollen and fungal spore aerobiology. *J Allergy Clin Immunol.* 2002;110:544–552.

40. *Global Estimates of Burden of Disease Caused by the Environment.* Geneva, Switzerland: World Health Organization; 2002.

41. American Thoracic Society. Environmental controls and lung disease: report of the ATS workshop on environmental controls and lung disease, Santa Fe, New Mexico, March 24–26. *Am Rev Respir Dis.* 1988;142:915–939.

42. American Lung Association, American Thoracic Society. Achieving healthy indoor air: report of the American Thoracic Society workshop. Sante Fe, New Mexico, November 16–18, 1995. *Am J Respir Crit Care Med.* 1997;156: 33S–64S.

43. Institute of Medicine, Committee on the Health Effects of Indoor Allergens, Division of Health Promotion and Disease Prevention. *Indoor Allergens: Assessing and Controlling Adverse Health Effects.* Washington, DC: National Academy Press; 1993.

44. Institute of Medicine, Committee on the Assessment of Asthma and Indoor Air. *Clearing the Air: Asthma and Indoor Air Exposures.* Washington, DC: National Academy Press; 2000.

45. *The Human Equation: Health and Comfort.* Atlanta, Ga: American Society of Heating, Refrigerating and Air Conditioning Engineers; 1989.

46. Mendell MJ, Fisk WJ, Kreiss K, et al. Improving the health of workers in indoor environments: priority research needs for a national occupational research agenda. *Am J Public Health.* 2002;92:1430–1440.

Breathless in Los Angeles: The Exhausting Search for Clean Air

Population growth and the proliferation of roadways in Southern California have facilitated a glut of mobile air pollution sources (cars and trucks), resulting in substantial atmospheric pollution.

Despite successful efforts over the past 40 years to reduce pollution, an alarming set of health effects attributable to air pollution have been described in Southern California. The Children's Health Study indicates that reduced lung function growth, increased school absences, asthma exacerbation, and new-onset asthma are occurring at current levels of air pollution, with sizable economic consequences.

We describe these findings and urge a more aggressive effort to reduce air pollution exposures to protect our children's health. Lessons from this "case study" have national implications. (*Am J Public Health.* 2003;93:1494–1499)

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ROADWAYS ARE AN IMPORTANT feature of the built environment in the United States, one that has developed as a result of massive investment and of public policy heavily influenced by private interests. Los Angeles once had a model public transit system based on an extensive and efficient network of electric trolleys. This system, along with the streetcar systems in 45 other cities, was bought and dismantled in the 1930s by National City Lines, a holding company owned by corporate partners in the automotive industry.[1] In Los Angeles alone, the people who made 280 million passenger trips a year on the mass transit system were forced into other forms of transportation. The automobile controlled the future of Los Angeles. Today, a large proportion of the US population lives in heavily populated "mega-cities," such as the greater Los Angeles region, and depends on automobiles for transportation and diesel trucks and trains for transporting goods.

Truck and automobile emissions are responsible for most of the air pollution in Southern California, with significant additional mobile source contributions from airports and the nation's largest marine port complex. In Southern California, episodic outdoor levels of ozone (O_3), particulate matter less than 10 microns in diameter (PM_{10}), and nitrogen dioxide (NO_2) historically have been among the highest in the United States, and they continue to exceed federal and state clean air guidelines.[2,3] Research conducted in the 1970s and 1980s confirmed acute effects of exposure to ozone and other traffic-related pollutants.[4,5] However, until recently, long-term health consequences were more uncertain, particularly among children, a population with rapidly growing lungs likely to be sensitive to the effects of air pollution.

THE CHILDREN'S HEALTH STUDY

The Children's Health Study (CHS), begun in Southern California in 1993, is one of the largest and most comprehensive investigations of the long-term consequences of air pollution on the respiratory health of children.[2,6] The purpose of this article is to summarize findings and future research strategies of the CHS and to discuss traffic-related regulatory implications. We do not provide a review of the literature on the health effects of air pollution, which can be found elsewhere.[7,8] Although many air pollution studies have been conducted in the Los Angeles area, the CHS is unique in its focus on chronic effects and its repeated evaluations of prospectively followed cohorts of children. Air quality across the CHS communities is comparable to conditions in other areas of the United States (Table 1), and thus the CHS example can be generalized to these regions.

More than 6000 public school children were recruited into the CHS from 12 different communities, which maximized the diversity in air pollution concentrations and mixtures across the region.[9] In total, nearly 4000 children in the 4th, 7th, and 10th grades were recruited at the initiation of the study in 1993, and an additional 2000 4th grade schoolchildren were recruited in 1996.[2,6,10] At study entry, a questionnaire assessed demographic characteristics of the family and the child's history of asthma, hay fever, and early life respiratory illnesses, as well as outdoor and physical activities, environmental tobacco smoke exposure, housing characteristics, and the family's health history. Diet and genetic characteristics have been evaluated in subsequent years.

In addition, yearly questionnaires assess the children's development of respiratory symptoms and their current activity patterns. Furthermore, lung function has been measured each year via spirometry.[11] School absences have been monitored to allow evaluation of the effects of pollution on acute respiratory illnesses.[12]

As a means of characterizing air quality in each of the 12 study communities, ambient concentrations of O_3, $PM_{2.5}$ (particulate matter less than 2.5 microns in diameter), PM_{10}, NO_2, and acid vapors have been measured at central monitoring stations (Table 1). Particle composition has been further characterized according to ion, elemental carbon, and organic carbon mass and sources of particulate pollution.[13] New microenvironmental models were developed to assess within-community variability in children's exposure based on respondent-reported housing characteristics—such as the use of air-conditioning—as well as on

TABLE 1—Annual Means of Major Pollutants Across the 12 Children's Health Study (CHS) Communities and in Other Selected US Cities

	County or Location	$PM_{2.5}$ Mass, $\mu g/m^3$	PM_{10}, $\mu g/m^3$	O_3, ppb	NO_2, ppb
CHS community[a]					
Lompoc	Santa Barbara	5	15	28	3
Lake Arrowhead	San Bernardino	6	19	71	10
Santa Maria	Santa Barbara	7	23	22	11
Lancaster	Los Angeles	7	29	50	16
Alpine	San Diego	7	27	42	15
Atascadero	San Luis Obispo	8	19	29	12
Lake Elsinore	Riverside	12	33	36	17
San Dimas	Los Angeles	16	32	26	32
Long Beach	Los Angeles	17	37	26	31
Upland	San Bernardino	19	37	28	37
Riverside	Riverside	20	48	37	28
Mira Loma	Los Angeles	27	67	32	28
Select US cities[b]					
Honolulu	Two-county average	4	15	11	. . .
Miami	Two-county average	11	24	23	11
Phoenix	Four-county average	11	41	33	28
Seattle	Three-county average	12	20	17	21
Houston	Three-county average	14	33	25	18
Sacramento	Two-county average	14	23	27	17
Philadelphia	Three-county average	15	38	28	27
New York City	Two-county average	16	22	19	34
Chicago	Three-county average	17	30	24	22
Atlanta	Two-county average	20	36	35	23
AAQS[c]	United States	15	50	. . .	53
AAQS[c]	California	12[d]	20[d,e]	. . .	. . .[f]

[a]Average PM and NO_2 concentrations based on data collected during all months of 1999 or 2000. Average ozone concentrations were based on data collected in May–September 1999 or 2000.
[b]Data from the Environmental Protection Agency's Aerometric Information and Retrieval System database.[71]
[c]Ambient air quality standards (no annual average standard exists for ozone).
[d]New California standard (June 2002).
[e]Annual geometric mean.
[f]One-hour maximum standard only (250 ppb).

TABLE 2—Associations Between Pollutants and Respiratory Health Outcomes From the Children's Health Study

Respiratory Health Outcome	Associated Pollutants[a]	Study
Slowed lung growth	NO_2, PM_{10}, $PM_{2.5}$, HNO_3	Gauderman et al.[10,15]; Avol et al.[18]
Asthma causation	O_3	McConnell et al.[21]
Asthma exacerbation	NO_2, PM_{10}	McConnell et al.[19]
Acute respiratory illness	O_3	Gilliland et al.[12]

[a]Main pollutants provided in the cited analyses. Pollutants were usually highly correlated; thus, effects may be due to mixtures.

patterns of time spent outside and physical activity patterns that might modify ambient exposures and individual doses.[9,14]

MAIN FINDINGS

In addition to the cross-sectional findings published in 1999,[2,6] the ongoing CHS project has yielded a wealth of data from the cohort follow-up, with a major focus on the chronic effects of air pollution. Chronic effects not previously reported were observed with respect to lung function growth and asthma, and short-term effects were observed with respect to school absences (Table 2).

Lung function growth was approximately 10% slower among children living in communities with higher NO_2 levels and other traffic-related pollutants, including nitric acid vapor and particulate matter.[15] This result was replicated in the second cohort of 4th-grade schoolchildren enrolled in 1996,[10] and the effect was observed among both normal and asthmatic children. These findings are consistent with longitudinal and cross-sectional findings of other investigations.[16,17] An improvement was seen in lung function growth rates among children who moved away from the more polluted communities to areas of lower PM_{10} concentrations, and growth rate retardation was observed among those moving to areas with higher concentrations.[18]

School absence rates increased with daily fluctuations in O_3 levels, particularly when levels rose in communities with low concentrations of PM_{10} and NO_2.[12] A modest increase of 20 parts per billion in 8-hour average ozone was associated with an 83% increase in school absences resulting from acute respiratory illnesses. Children with asthma experienced more bronchitis and persistent phlegm production if they lived in communities with more NO_2 or particulate pollution.[19] This finding accords with results from the Harvard Six Cities Study.[20] Given the fact that people with asthma have more bouts of bronchitis than those without asthma, even a modest increased risk in bronchitis rates due to air pollution may result in a considerable burden in terms of increased asthma symptoms in children.[13]

Children who played team sports and spent more time outside in communities with high ozone levels had a higher incidence of newly diagnosed asthma.[21] In communities with low ozone levels, playing team sports was not associated with an increased risk of asthma. Because exercising children exhibit increased rates of ventilation, playing team sports increases doses of ozone and other lung pollutants. This finding is noteworthy, because it was previously believed that air pollution exacerbated asthma among children who already have the disease rather than causing new-onset asthma. A recent Dutch cohort study of newborn children also revealed increased asthma incidence rates among children living in more polluted communities.[22]

FUTURE RESEARCH STRATEGIES

Ongoing components of the CHS aim to determine whether deficits in lung function growth from air pollution in childhood

result in diminished maximum attained lung function (which occurs in early adulthood) and to evaluate factors, such as asthma, that may modify the effect of air pollution on attained lung function. For example, children reporting recent respiratory illnesses exhibited measurable and significant decrements in pulmonary function, decrements that were most marked in the small airways.[23] By following the cohorts into adult life and repeatedly measuring lung function, it should be possible to distinguish the main effects of acute and cumulative exposures.

Limitations of the CHS are discussed in the articles listed in Table 2. A major limitation involved the exposure assignment of community-based mean values; long-term average exposures to nitrogen oxides, acids, and particulate matter were highly correlated across the 12 CHS communities. New statistical methods and exposure models under development may help to disentangle these co-pollutant effects (K. Berhane, D.O. Stram, W.J. Gauderman, and D.C. Thomas, unpublished data, 2003) and to determine whether source-specific exposures (e.g., exposures to traffic, refineries, power plants, port activities, diesel trains, construction equipment, and wood smoke) are also important.[24,25] Pollutants that were of little concern at the time the CHS began have now been identified as important respiratory hazards and could be incorporated into future exposure assignment approaches (e.g., polycyclic aromatic hydrocarbons associated with particles from diesel exhaust[26] and ultrafine particles [less than 0.1 micron in aerodynamic diameter]).[27]

The association between ozone exposures among children playing team sports and new-onset asthma requires further study. Because asthma prevalence rates vary widely between communities for reasons that are not well understood,[28] examining within-community variability in air pollution may be an important strategy for clarifying the effects of air pollution on asthma. Preliminary results from the CHS suggest that residential proximity to traffic is associated with asthma prevalence rates.[29]

In 2002, the CHS began recruitment of a new cohort of 6000 children aged 5 to 7 years, and this cohort provides an opportunity to evaluate the laboratory observation that co-exposure to ozone or to particulate matter in diesel exhaust enhances the effect of allergens in producing asthma and allergies in animal models.[30,31] Improved techniques for modeling lung function, developed for the CHS, have demonstrated reduced lung function in asthmatic children, even before diagnosis,[32] and these methods are now being applied in an examination of the joint effects of air pollution and asthma on lung function and lung function growth at different ages (K. Berhane, D.O. Stram, W.J. Gauderman, and D.C. Thomas, unpublished data, 2003).

The evidence emerging from the CHS supports the hypothesis that genetics and diet are important for respiratory health, and the hypothesis that they may modify the effect of oxidant pollutants is under active investigation.[33,34] The observed interaction in the CHS between in utero tobacco smoke exposure and asthma prevalence and lung function is a model for similar interactions that might occur with air pollution.[35,36] The effect of in utero tobacco smoke exposure on asthma risk was observed primarily in children with a null genotype for glutathione S-transferase M1; (the null genotype results in a lack of this antioxidant enzyme).[37] Observed protective relationships of lung function with dietary magnesium and potassium[38] and with vitamin C[39] suggest potential avenues for primary prevention.[40]

REGULATORY IMPLICATIONS

The development of good public health policy is based on evaluating overall scientific evidence[7] rather than relying on findings from a single study. However, the effects of air pollution on health observed in the CHS provide an example of evidence that improvements in air quality would lessen both acute and chronic respiratory illnesses among children. According to the CHS results, the successful reductions in ozone levels in Southern California have prevented more than 2.8 million school absences involving an economic cost of more than $220 million.[41,42] The observation that lung function increased in CHS children who moved to cleaner communities (and decreased in children who moved to more polluted communities)[18] strongly suggests that chronic lung function effects are caused by air pollution. Thus, both better compliance with existing standards and further improvements in air quality are needed to protect children's health.

We distinguish 2 approaches to reducing exposure to air pollution. "Primary strategies" that reduce ambient concentrations of air pollutants must be the main focus of regulatory action, and "secondary strategies" that reduce children's exposure to air pollution without improving ambient air quality may have a complementary and temporary role (Table 3). Given traffic's dominant role in Southern California, and the fact that the CHS revealed respiratory health effects associated with a number of traffic-related pollutants, we have chosen to focus on traffic-related emissions. Mobile sources are generally the dominant national contributor to ambient urban air pollution.[43,44]

PRIMARY STRATEGIES: CUTTING EMISSIONS

Ambient air quality standards for major air pollutants are set to protect public health, and vigorous enforcement of compliance with these standards is a principal regulatory tool in the United States. The standards themselves have been based largely on acute effect studies. The California Environmental Protection Agency, for example, estimates that 400000 episodes of upper and lower respiratory symptoms in children could be prevented each year in California alone if the new $PM_{2.5}$ standard of 12 $\mu g/m^3$ (annual mean) were met.[13] Results from the CHS and other recent studies suggest that long-term effects have been underestimated and that the benefits of meeting current standards would be even larger than the state's estimates.[13,45,46]

Compelling evidence from the CHS that lung function is impaired by air pollution is directly relevant to the current debate over the regulation of particulate pollutants. In addition, the emerging evidence that air pollution is a factor in the development of asthma is relevant to the new federal ozone standards under consideration. Nearly 70 million Americans live in areas that exceed existing ozone standards, nearly 10 million live in areas exceeding NO_2 standards, and more

TABLE 3—Examples of Primary and Secondary Policy Strategies to Reduce Children's Exposure to Traffic-Related Air Pollution

Type of Strategy	Policy Target	Intervention
Primary (reduce air pollution)	Technology	Reduce emissions in new vehicles
		Retrofit school buses and diesel trucks
		Inspect vehicle emissions of all engines
		Increase fuel economy
		Use clean fuels
		Develop zero emission vehicles
	Urban design	Invest in public transport
		Limit urban sprawl
		Build bicycle and walking paths
	Behavior	Use carpools
		Take the bus to work
		Walk/bicycle
		Use school buses or walk to school instead of driving
		Forbid idling of school buses
Secondary (reduce exposure or susceptibility)	Technology	Condition or filter air in schools
	Urban design	Limit vehicles near schools
		Separate schools from roadways
	Behavior	Avoid streets with heavy traffic
		Review guidelines for children with asthma
		Reduce outdoor activity when pollution is high
		Consider antioxidant supplements in high-pollution areas

than 20 million live in areas exceeding standards set for PM_{10}.[4] Clearly, complying with current air quality standards would benefit children's health, and the new evidence strongly endorses the strategy of the California Environmental Protection Agency, which recently set stricter standards (Table 1).[13]

Examples of interventions that would reduce pollution and help achieve compliance with air quality standards are presented in Table 3. A more extensive review of relevant vehicle technology, urban design, and behavioral changes is available elsewhere.[47] Better engine technology has dramatically reduced emissions, and new policies continue to promote this trend[46,48]; new fuel-efficient automobiles currently on the market travel 40 to 50 miles per gallon and have very low emissions, but the average new car sold in the United States is only half as efficient.[49] In 1999, fuel economy levels in the United States reached their lowest value in 15 years, a trend in large part due to an increase in sales of sport utility vehicles.[50] In 2002, automakers pushed Congress to reject any substantial legislated increase in fuel economy standards.[51] Without this regulatory pressure, there is little incentive for companies to promote more fuel-efficient cars.

There is an urgent need for incentives that lead to faster implementation of the "best available technology." However, this goal is hampered by stalled or failed regulatory policy. Delays due to prolonged legal challenges to new air quality standards, long phase-in periods for cleaner diesel engines, and exemptions and delays in holding sport utility vehicles and other larger vehicles (e.g., trucks, ships, school buses) to the same standards as smaller cars create disincentives in regard to the overall reduction of air pollution.

No single policy tool is likely to be sufficient to achieve marked reductions in air pollution. A long-term, integrated set of policies to rebuild communities to make them less dependent on fossil fuels for transportation would yield benefits that go far beyond improved health. For example, policies that promote the rapid development and implementation of very low– or zero-emission vehicles, combined with strong incentives such as emission-related taxes, road tolls, and fuel prices that would cover all direct and indirect costs of traffic (including costs related to health damage), could strongly influence consumer choice.[52,53] Such a strategy would improve children's respiratory health, mitigate the long-term threats posed by greenhouse gas emissions from mobile sources, and reduce the current heavy dependence on foreign oil.[8,54–56]

Prioritizing policies that lead to zero emission vehicle fleets would also avoid the trade-offs between health and the environment inherent in the promotion of diesel automobiles as a solution to the problem of greenhouse gas production.[57] In fact, diesel cars are associated with very little savings of energy or reduction in carbon dioxide levels,[53] and they are associated with much higher emission levels of unhealthy particulates.

The World Health Organization[58] has also proposed integrated regulatory approaches. For example, programs promoting bicycling and walking as transportation options for children[59,60] could (1) decrease automobile emissions; (2) reduce the time that children spend in cars, where rates of exposure to certain pollutants and toxic compounds are up to 10 times higher than outdoors[61]; and (3) promote healthy physical activity in the current generation of increasingly sedentary and obese children.[62]

SECONDARY STRATEGIES: REDUCING EXPOSURE, NOT EMISSIONS

Even with the most aggressive efforts to reduce emissions, the current generation of children in the Los Angeles metropolitan area will suffer adverse health effects from air pollution. Thus, policies designed to reduce children's exposure to air pollution should be considered. Examples that merit further discussion include the following:

- In communities with high pollution levels, air-conditioning or filtration in schools would reduce indoor exposure to outdoor pollutants, especially ozone.[14]
- Evidence suggests that fresh traffic exhaust is hazardous, independent of background concentrations.[29,63,64] Prudent policy would dictate that new schools, day-care centers, parks, and sports fields not be sited adjacent to roads with high traffic volumes. Re-siting of schools or changes in traffic regimens around schools with exceptionally high levels of emissions might be considered.
- Children with asthma are a susceptible group. A task force in-

volving health care professionals and air quality regulators could develop clinical guidelines for the care of asthmatic children. These guidelines should include recommendations on how to reduce exposure to ambient air pollution. This is an important public health issue, in that several CHS communities exhibit asthma prevalence rates greater than 20% and high rates of new-onset asthma in schoolchildren.[21]

• In Southern California on high pollution days, warnings are issued to schools with recommendations for children to reduce outdoor exercise. Review of the action levels triggering such warnings might be appropriate. Pollution levels can be forecast up to 5 days in advance in many urban areas, and these forecasts could be used to improve compliance with existing recommendations.

• Evidence is increasing that antioxidant intake protects children from acute oxidative damage due to air pollution exposure.[39,40,65] Consideration should be given to vitamin C supplementation in schools located in areas with high oxidant levels.

TENSIONS BETWEEN DIFFERENT REDUCTION STRATEGIES

In the long term, secondary reduction strategies are limited and have the potential to increase other public health risks. For example, limiting exercise on high pollution days to reduce doses of pollutants entering the lungs may increase the risk of diseases associated with children's increasingly sedentary lifestyles.[62] Walking to school, rather than driving with a parent, may increase children's exposure unless walking routes and traffic patterns around schools are taken into account.[66,67]

Air-conditioning in schools would increase energy consumption and emissions from power plants. Furthermore, air-conditioning may contribute to other health problems, such as sick building syndrome.[68] Although promotion of dietary antioxidant supplements such as vitamin C or E may be a promising intervention, there is some evidence that vitamin C may act as a prooxidant,[69] and further evaluation of such an intervention is required before programs could be implemented.

Finally, people's individual decisions to move to more distant, seemingly less polluted suburban areas may result in overall increased levels of emissions if commuting time increases.[70] In the long term, secondary strategies will fail to protect the public's health unless they are complementary to emission reduction strategies.[8,13,52]

CONCLUSIONS

The CHS and other studies contribute to the strong evidence that air pollution at levels permitted by current standards is harming children's health. In addition, on the basis of emerging evidence of chronic effects, risk assessments used in setting regulatory policy most likely underestimate the harm done by currently permissible levels. Our children deserve a visionary public health regulatory policy that addresses these challenges and protects them from sources of air pollution. A policy framework designed to protect children should focus on reducing emissions in the short term. Long-term policies must accomplish a decisive move toward low- to zero-emission vehicles with high fuel economy ratings. ■

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Contributors

N. Künzli led the writing of the article. R. McConnell provided significant writing and technical contributions. D. Bates developed many of the foundations for the article and commented on all versions. T. Bastain contributed to research and to editing. A. Hricko provided policy implications and suggestions and contributed to editing and research. F. Lurmann and E. Avol provided technical expertise and suggestions related to exposure assessments. F. Gilliland provided technical expertise and suggestions regarding genetic epidemiology. J. Peters made significant contributions to writing and editing.

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References

1. Newman P, Kenworthy J. *Sustainability and Cities: Overcoming Automobile Dependence.* Washington, DC: Island Press; 1999.

2. Peters JM, Avol E, Navidi W, et al. A study of twelve Southern California communities with differing levels and types of air pollution: I. Prevalence of respiratory morbidity. *Am J Respir Crit Care Med.* 1999;59:760–767.

3. American Lung Association. State of the air 2002: grading the risk. Available at: http://www.lungusa.org/air2001/risk02.html. Accessed December 15, 2002.

4. American Thoracic Society. Health effects of outdoor air pollution. *Am J Respir Crit Care Med.* 1996;153:3–50.

5. American Thoracic Society. Health effects of outdoor air pollution: part 2. *Am J Respir Crit Care Med.* 1996;153: 477–498.

6. Peters JM, Avol E, Gauderman WJ, et al. A study of twelve Southern California communities with differing levels and types of air pollution: II. Effects on pulmonary function. *Am J Respir Crit Care Med.* 1999;159:768–775.

7. Brunekreef B, Holgate ST. Air pollution and health. *Lancet.* 2002;360: 1233–1242.

8. Bates DV, Caton RB. *A Citizen's Guide to Air Pollution.* 2nd ed. Vancouver, British Columbia: David Suzuki Foundation; 2002.

9. Navidi W, Thomas D, Langholz B, Stram D. Statistical methods for epidemiologic studies of the health effects of air pollution. *Res Rep Health Eff Inst.* 1999;86:1–50.

10. Gauderman WJ, Gilliland GF, Vora H, et al. Association between air pollution and lung function growth in Southern California children: results from a second cohort. *Am J Respir Crit Care Med.* 2002;166:76–84.

11. Enright PL, Linn WS, Avol EL, Margolis HG, Gong H Jr, Peters JM. Quality of spirometry test performance in children and adolescents: experience in a large field study. *Chest.* 2000;118:665–671.

12. Gilliland FD, Berhane K, Rappaport EB, et al. The effects of ambient air pollution on school absenteeism due to respiratory illnesses. *Epidemiology.* 2001;12:43–54.

13. *Public Hearing to Consider Amendments to the Ambient Air Quality Standards for Particulate Matter and Sulfates: Staff Report.* Sacramento, Calif: Air Resources Board, California Environmental Protection Agency; 2002.

14. Avol EL, Navidi WC, Colome SD. Modeling ozone levels in and around Southern California homes. *Environ Sci Technol.* 1998;32:463–468.

15. Gauderman WJ, McConnell R, Gilliland F, et al. Association between air pollution and lung function growth in Southern California children. *Am J Respir Crit Care Med.* 2000;162:1383–1390.

16. Frischer T, Studnicka M, Gartner C, et al. Lung function growth and ambient ozone: a three-year population study in school children. *Am J Respir Crit Care Med.* 1999;160:390–396.

17. Raizenne M, Neas LM, Damokosh AI, et al. Health effects of acid aerosols on North American children: pulmonary

function. *Environ Health Perspect.* 1996; 104:506–514.

18. Avol EL, Gauderman WJ, Tan SM, London SJ, Peters JM. Respiratory effects of relocating to areas of differing air pollution levels. *Am J Respir Crit Care Med.* 2001;164:2067–2072.

19. McConnell R, Berhane K, Gilliland F, et al. Air pollution and bronchitic symptoms in Southern California children with asthma. *Environ Health Perspect.* 1999;107:757–760.

20. Dockery DW, Speizer FE, Stram DO, Ware JH, Spengler JD, Ferris BG Jr. Effects of inhalable particles on respiratory health of children. *Am Rev Respir Dis.* 1989;139:587–594.

21. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet.* 2002;359:386–391.

22. Brauer M, Hoek G, Van Vliet P, et al. Air pollution from traffic and the development of respiratory infections and asthmatic and allergic symptoms in children. *Am J Respir Crit Care Med.* 2002; 166:1092–1098.

23. Rappaport EB, Gilliland FD, Linn WS, Gauderman WJ. Impact of respiratory illness on expiratory flow rates in normal, asthmatic, and allergic children. *Pediatr Pulmonol.* 2002;34:112–121.

24. Schauer JJ, Fraser MP, Cass GR, Simoneit BR. Source reconciliation of atmospheric gas-phase and particle-phase pollutants during a severe photochemical smog episode. *Environ Sci Technol.* 2002;36:3806–3814.

25. Schauer JJ, Cass GR. Source apportionment of wintertime gas-phase and particle-phase air pollutants using organic compounds as tracers. *Environ Sci Technol.* 2000;34:1821–1832.

26. Li N, Wang M, Oberley TD, Sempf JM, Nel AE. Comparison of the pro-oxidative and proinflammatory effects of organic diesel exhaust particle chemicals in bronchial epithelial cells and macrophages. *J Immunol.* 2002; 169:4531–4541.

27. Li N, Sioutas C, Cho A, et al. Ultrafine particulate pollutants induce oxidative stress and mitochondrial damage. *Environ Health Perspect.* In press.

28. International Study of Asthma and Allergies in Childhood Steering Committee. Worldwide variation in prevalence of symptoms of asthma, allergic rhinoconjunctivitis, and atopic eczema: ISAAC. *Lancet.* 1998;351:1225–1232.

29. McConnell R, Berhane K, Lurmann F, et al. Traffic and asthma prevalence in children. *Am J Respir Crit Care Med.* 2002;165:A492.

30. Diaz-Sanchez D. The role of diesel exhaust particles and their associated polyaromatic hydrocarbons in the induction of allergic airway disease. *Allergy.* 1997;52(suppl):52–56.

31. Miller LA, Hyde DM, Gershwin LJ, et al. The effect of house dust mite aeroallergen and air pollutant exposures during infancy. *Chest.* 2003;123(suppl 3):434S.

32. Berhane K, McConnell R, Gilliland F, et al. Sex-specific effects of asthma on pulmonary function in children. *Am J Respir Crit Care Med.* 2000;162:1723–1730.

33. Gilliland FD, Gauderman WJ, Vora H, Rappaport E, Dubeau L. Effects of glutathione-S-transferase M1, T1, and P1 on childhood lung function growth. *Am J Respir Crit Care Med.* 2002;166: 710–716.

34. Gilliland FD, Rappaport EB, Berhane K, et al. Effects of glutathione S-transferase P1, M1, and T1 on acute respiratory illness in school children. *Am J Respir Crit Care Med.* 2002;166:346–351.

35. Gilliland FD, Li YF, Peters JM. Effects of maternal smoking during pregnancy and environmental tobacco smoke on asthma and wheezing in children. *Am J Respir Crit Care Med.* 2001; 163:429–436.

36. Gilliland FD, Berhane K, McConnell R, et al. Maternal smoking during pregnancy, environmental tobacco smoke exposure and childhood lung function. *Thorax.* 2000;55:271–276.

37. Gilliland FD, Li YF, Dubeau L, et al. Effects of glutathione S-transferase M1, maternal smoking during pregnancy, and environmental tobacco smoke on asthma and wheezing in children. *Am J Respir Crit Care Med.* 2002;166:457–463.

38. Gilliland FD, Berhane KT, Li YF, Kim DH, Margolis HG. Dietary magnesium, potassium, sodium, and children's lung function. *Am J Epidemiol.* 2002; 155:125–131.

39. Gilliland F, Li Y, Peters J. Effects of vitamin A, C, and E intake on children's lung function. *Am J Respir Crit Care Med.* 2001;163:A37.

40. Romieu I, Sienra-Monge JJ, Ramirez-Aguilar M, et al. Antioxidant supplementation and lung functions among children with asthma exposed to high levels of air pollutants. *Am J Respir Crit Care Med.* 2002;166:703–709.

41. *Latest Findings on National Air Quality: 2000 Status and Trends.* Research Triangle Park, NC: Office of Planning and Standards, US Environmental Protection Agency; 2001. EPA publication 454/K-01-002.

42. Hall JV, Brajer V, Lurmann F, Wu J. *Economic Valuation of Ozone-Related School Absences in the South Coast Air Basin.* Sacramento, Calif: California Air Resources Board; 2002. Report STI-901250-2174-FR.

43. Commission on Geosciences, Environment, and Resources. *Modeling Mobile-Source Emissions.* Washington, DC: National Academy Press; 2000.

44. *Automobile Emissions: An Overview.* Washington, DC: US Environmental Protection Agency; 1994. EPA publication 400-F-92-007.

45. *Final Report to Congress on Benefits and Costs of the Clean Air Act, 1970-1990.* Washington, DC: US Environmental Protection Agency; 1997. EPA publication 410-R-97-002.

46. *Regulatory Impact Analysis-Heavy-Duty Engine and Vehicle Standards and Highway Diesel Fuel Sulfur Control Requirements.* Washington, DC: US Environmental Protection Agency; 2000. EPA publication 420-R-00-026.

47. Mennell M, Bhattacharya KK. Air quality management. In: Bates DV, Caton RB, eds. *A Citizen's Guide to Air Pollution.* 2nd ed. Vancouver, British Columbia, Canada: David Suzuki Foundation; 2002:277–338.

48. National Research Council. *Estimating the Public Health Benefits of Proposed Air Pollution Regulation.* Washington, DC: National Academy Press; 2002.

49. Hellman KH, Heavenrich RM. *Light Duty Automative Technology and Fuel Economy Trends, 1975-2001.* Washington, DC: US Environmental Protection Agency; 2001. EPA publication 420-R-01-008.

50. *National Air Quality and Emissions Trends Report, 1999.* Research Triangle Park, NC: Office of Air Quality Planning and Standards, US Environmental Protection Agency; 2001. EPA publication 454/R-01-004.

51. Power S. U.S. proposes modest increases in fuel-economy standards. *Wall Street Journal.* December 13, 2002:B2.

52. *Strategies to Reduce Greenhouse Gas Emissions From Road Transport: Analytical Methods.* Paris, France: Organisation for Economic Cooperation and Development; 2002.

53. Schipper L, Marie-Lilliu C, Fulton L. *Diesel in Europe: Analysis of Characteristics, Usage Patterns, Energy Savings, and CO2 Emission Implications.* Paris, France: Energy Efficiency Technology Office, International Energy Agency; 2000.

54. Cifuentes L, Borja-Aburto VH, Gouveia N, Thurston G, Davis DL. Climate change: hidden health benefits of greenhouse gas mitigation. *Science.* 2001;293:1257–1259.

55. Dora C. A different route to health: implications of transport policies. *BMJ.* 1999;318:1686–1689.

56. Davis DL, Krupnick A, McGlynn G. *Ancillary Benefits and Costs of Greenhouse Gas Mitigation: Proceedings of an IPCC Co-Sponsored Workshop.* Paris, France: Organisation for Economic Cooperation and Development; 2000.

57. Ball J. Clean-air czar of California shifts to accept diesel engines. *Wall Street Journal.* October 24, 2002:A1.

58. *Transport, Environment and Health.* Copenhagen, Denmark: World Health Organization; 2000.

59. California Air Resources Board. Improving California air quality through increased bicycling: fact sheet from the California Bicycle Summit, March 5-6, 1998. Available at: http://www.arb.ca.gov/planning/tsaq/bicycle/factsht.htm. Accessed November 15, 2002.

60. Assembly Bill 1475. California State Legislature (1999).

61. Rodes C, Sheldon L, Whitaker D, et al. *Measuring Concentrations of Selected Air Pollutants Inside California Vehicles: Final Report.* Research Triangle Park, NC: Research Triangle Institute; 1998.

62. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity: a systematic review. *Am J Prev Med.* 2002; 22(suppl 4):73–107.

63. Brunekreef B, Janssen NA, de Hartog J, Harssema H, Knape M, van Vliet P. Air pollution from truck traffic and lung function in children living near motorways. *Epidemiology.* 1997;8:298–303.

64. van Vliet P, Knape M, de Hartog J, Janssen N, Harssema H, Brunekreef B. Motor vehicle exhaust and chronic respiratory symptoms in children living near freeways. *Environ Res.* 1997;74:122–132.

65. Bowler RP, Crapo JD. Oxidative stress in allergic respiratory diseases. *J Allergy Clin Immunol.* 2002;110:349–356.

66. Gulliver J. *Space-Time Modelling of Exposure to Air Pollution Using GIS* [dissertation]. Northampton, England: University of Leicester; 2002.

67. Chan LY, Lau WL, Zou SC, Cao ZX, Lai SC. Exposure level of carbon monoxide and respirable suspended particulate in public transportation modes while commuting in urban area of Guangzhou, China. *Atmospheric Environment.* 2002;36:5831–5840.

68. Wargocki P, Sundell J, Bischof W, et al. Ventilation and health in non-industrial indoor environments: report from a European multidisciplinary scientific consensus meeting (EUROVEN). *Indoor Air.* 2002;12:113–128.

69. Podmore ID, Griffiths HR, Herbert KE, Mistry N, Mistry P, Lunec J. Vitamin C exhibits pro-oxidant properties. *Nature.* 1998;392:559.

70. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002; 117:201–217.

71. Environmental Protection Agency. Aerometric Information and Retrieval System database. Available at: http://www.epa.gov/ttn/airs. Accessed December 1, 2002.

The Impact of Community Design and Land-Use Choices on Public Health: A Scientific Research Agenda

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The design of a community's built environment influences the physical and mental health of its residents. Because few studies have investigated this relationship, the Centers for Disease Control and Prevention hosted a workshop in May 2002 to help develop a scientific research agenda on these issues.

Workshop participants' areas of expertise included physical activity, injury prevention, air pollution, water quality, urban planning, transportation, architecture, epidemiology, land use, mental health, social capital, housing, and social marketing. This report describes the 37 questions in the resulting research agenda.

The next steps are to define priorities and obtain resources. The proposed research will help identify the best practices for designing new communities and revitalizing old ones in ways that promote physical and mental health. (*Am J Public Health.* 2003;93:1500–1508)

The design choices we make in our homes, schools, workplaces, communities, and transportation systems can have major effects on health,[1] which is defined by the World Health Organization as "a state of complete physical, mental, and social well-being and not merely the absence of disease or infirmity."[2] A healthy community protects and improves the quality of life for its citizens, promotes healthy behaviors and minimizes hazards for its residents, and preserves the natural environment.

Increasing evidence suggests that land-use and transportation decisions can facilitate or obstruct the creation and maintenance of healthy communities. The design of cities, neighborhoods, and individual buildings can affect levels of physical activity,[3] which is an important factor in the prevention of obesity and its associated adverse health consequences.[4] Community design influences the amount to which its residents are dependent on automobiles, whose use contributes to air pollution, motor vehicle crashes, and pedestrian injuries.[5] The design of the built environment affects the ability of persons with disabilities to be physically active and to be socially integrated into their community.[6] The mental health of individuals[7] and a community's social capital[8] may be influenced by the design of the built environment. Environmental justice is also a concern because persons with low socioeconomic status may suffer disproportionately from the adverse consequences of transportation and land-use decisions in their communities.[9]

Although some research has been done to document the specific interactions between the built environment and health, it is often conducted within one discipline, and results are typically not widely shared across disciplines. Community leaders and public health officials need to know more about which community design and land-use choices are most effective in improving the physical, mental, and social well-being of the public. The Centers for Disease Control and Prevention (CDC) has collaborated with an interdisciplinary group of academic researchers, public health practitioners, and professional organizations to create a scientific research agenda that highlights areas in which further investigations are needed to improve our understanding of these issues.

METHODS

To help develop a research agenda, the CDC invited external experts to a 1-day workshop held in May 2002 in Atlanta. The workshop participants represented a wide range of disciplines, including physical activity, injury prevention, air pollution, water quality, urban planning, transportation, architecture, epidemiology, land use, mental health, social capital, health policy, housing, and social marketing.

Before the workshop, participants were asked to provide, from their areas of expertise, 2 scientific research questions "that if answered would further our knowledge of the relation of public health to community design and land-use choices." During the workshop, these draft research questions were refined and edited by small groups, and the full workshop panel then discussed them further and made additions. After the workshop, a summary of these discussions was circulated for further input to other individuals and organizations from various public health and other professional backgrounds. Although not representing a full consensus of all persons involved, the current report includes ideas from dozens of individuals, all of whom were offered the opportunity to comment on the document as it was nearing completion.

RESULTS

The workshop participants and subsequent contributors generated 37 research questions designed to extend scientific knowledge of the relationship between public health and community design and land-use choices. The questions were grouped into themes including research methods, physical activity and transportation choices, schools and children, unintentional and intentional injuries, impact on persons with disabilities, air and water quality, mental health, social capital, environmental justice, and cross-cutting issues. Although no formal priority-setting process was conducted, this report's authors selected 18 questions for further elaboration (discussed below), considering factors such as utility, feasibility, generalizability, and affordability. The remaining questions are summarized in Table 1. For all questions, some possible re-

TABLE 1—Additional Research Questions Regarding the Impact of Community Design and Land Use Choices on Public Health[a]

Research Question	Research Design
Physical activity and transportation mode choice	
a. What are the physical and social barriers to walking and biking for transportation and for recreation?	Conduct a cross-sectional survey of adults and children in urban, suburban, and rural settings.
b. Does improved design to encourage walking/biking lead to a decline in per capita automobile use?	Examine before and after person-hours of walking and biking and per capita vehicle miles traveled in redesigned or revitalized neighborhoods.
c. For decreasing automobile dependence and increasing physical activity, is it more important to improve the design of residential areas, of commercial areas, or of the transportation links between them?	Examine before and after per capita miles traveled riding in vehicles, walking, and bicycling, and overall physical activity in redesigned or revitalized residential and commercial areas.
Injury prevention	
a. Compared with areas with a narrow range of housing values, what are the impacts of mixed-income neighborhoods on public safety and public health, such as crime rates, rates of chronic disease, and social cohesion?	Examine before and after crime victimization rates, health measures, and social capital in communities where urban redesign and revitalization is planned, controlling for confounders. Also conduct a survey of residents' fears and perceived risk compared with true risk.
b. How do features of the built environment affect risk of unintentional injury in vulnerable populations such as children, the elderly, and persons with disabilities?	Examine injury rates in vulnerable persons in traditional neighborhoods and in newer automobile-dependent neighborhoods. Examine before and after community injury rates as urban redesign and renovation occurs.
c. What is the relationship between the health of neighborhood residents and local crime rates, in that fear of potential victimization may discourage physical activity and social interactions even in pedestrian-friendly communities?	Conduct a cross-sectional survey of health, physical activity, and characteristics of the built environment in neighborhoods with high and low crime rates. Conduct surveys of residents' perceived risks of victimization compared with true risks in the same communities.
d. What is the relationship between characteristics of the built environment and vulnerability to natural disasters and to terrorism?	Conduct computer simulations of the impact of various natural disaster and terrorism scenarios on different types of neighborhoods. For example, the time required for emergency response and community evacuation can be tested for various street patterns.
Air quality and climate change	
a. What is the relationship between the age and maintenance of houses, schools, and other buildings and the incidence of asthma attacks, especially in urban areas, and are such adverse health events improved when communities are renovated?	Conduct a longitudinal study of frequency of asthma attacks compared with neighborhood building conditions, including age, maintenance, ventilation, infestation, and other factors that may contribute to asthma, before and after community renovations.
b. How do factors contributing to climate change differ between areas with and without strong regional planning processes?	Compare greenhouse gas emissions levels and loss of farmland and green space in communities with and without good regional planning.
Public policy and other crosscutting issues	
a. What are the political, economic, and psychological barriers to building pedestrian-oriented mixed-use communities?	Interview decisionmakers and conduct focus groups in new communities to examine the political, economic, and psychological factors that led to desirable and undesirable designs in those communities.
b. What are the barriers, such as lack of knowledge or personal rationalizations, that (1) prevent planners from considering public health impacts in their decisions and (2) prevent public health officials from becoming more involved in the planning process?	Conduct focus groups with planners and public health practitioners to identify these barriers, and then develop partnerships to work on addressing these barriers.
c. What factors, such as differences in education, funding, and politically active citizenry, contribute to the disparities in desirable design elements between lower and upper socioeconomic communities?	Conduct interviews and cross-sectional surveys with planners and builders of new communities designed for persons with low and high income levels.
d. What are the effects on health of design and policy decisions that affect urban housing quality, including housing construction, rehabilitation, and management?	Conduct cross-sectional surveys with builders, repairers, and managers of urban housing units and periodic interviews with residents of those units.
e. What interventions to improve housing, particularly low-income housing, will lead to better health in children and adults, especially in relation to asthma, mold-induced illness, lead poisoning, carbon monoxide poisoning, and unintentional injuries?	Assess the health status of children and adults living in low-income housing before and after implementation of selected housing interventions.
f. How can incentives (e.g., location efficient mortgages) and disincentives (e.g., impact fees) be used to encourage community designs that promote health for the diversity of groups (e.g., race/ethnicity, class, life stage, citizenship, disability status) who live in the United States?	Conduct interviews and cross-sectional surveys with policymakers, regional planners, developers, and bankers in a variety of communities.

Continued

TABLE 1—*Continued*

g. What strategies are used in successful well-designed communities to maintain public policies favorable to health and quality of life?	Conduct interviews with policymakers and managers in existing well-designed communities.
h. As part of including community residents in the planning process, what is the perceived value in terms of health, safety, and desirability that communities place on specific design elements such as sidewalks, green spaces, and community centers?	Conduct focus groups and cross-sectional surveys with random samples of citizens in existing well-designed and poorly designed communities.
i. What analytic techniques from fields other than public health, such as urban planning, transportation engineering, and architecture, might be useful for examining health and community design issues?	Conduct a literature review of fields related to community design to identify potentially useful analytic techniques from other disciplines.
j. How are urban, suburban, and rural built environments changing over time in terms of density, connectivity, walkability, travel patterns, and health outcomes?	Use existing surveillance systems of environmental characteristics and health outcomes and develop new tracking systems where needed.

[a]This table describes research questions suggested by participants at the May 2002 workshop described in the "Methods" section of the text but excludes research questions described in the "Results" section.

search designs are suggested, although we recognize that investigators may design valuable studies using methods other than those considered in this report.

Research Methods and Data Sources

Much research relevant to the relationship between health and community design has been conducted by professionals in other fields, including transportation engineering, urban and regional planning, architecture, atmospheric chemistry, psychology, sociology, and political science. Identifying relevant data sources, measures, and research methods in these fields is important; new methods and measures can be developed as needed.

Identifying exposure measurements. Research question: What are the best measures of the physical environment that may be relevant to health? How do these measures relate to the health of populations in specific urban and suburban environments? Neighborhood-level examples might include the presence of front porches, sidewalks, traffic calming, and green space; community-level examples might include residential density, housing features, land-use mix, quantity and quality of public space, connectivity, and transportation systems.[10] High levels of noise, graffiti, broken windows, and liquor stores may reflect poor community health.

Research design: Potential measures might be identified by a literature review of research in related fields such as urban and regional planning, land use, transportation design, sustainable development, and healthy cities, especially focusing on indicators. Longitudinal and quasi-experimental studies would be useful for documenting which of these measures are associated with health outcomes, in what ways the measures cluster, and what new measures might be useful.

Defining guidelines. Research question: Analogous to ideal body weight, what are desirable levels of health-related parameters of the physical environment, such as land-use mix, walkability, indoor environmental quality, or proximity to green space? The Leadership in Energy and Environmental Design guidelines[11] may serve as a model for developing health-related community design guidelines. New guidelines should be consistent with standards for accessibility for persons with disabilities.[12]

Research design: Analytic studies are needed to define the levels of the parameters associated with quantifiable health benefits or adverse outcomes. Natural experiments may provide useful data for some parameters. As with other public health interventions, proposed guidelines should be assessed for safety, efficacy, costs, and unintended consequences. For example, narrow streets designed to encourage walking could interfere with response time for emergency vehicles. Data on proposed guidelines should be systematically reviewed through a formal meta-analytic approach or other structured review process, such as that used to create the Guide to Community Preventive Services.[13] Further research would be valuable in areas where insufficient evidence is available.

Physical Activity, Obesity, and Transportation Choices

Despite the proven benefits of a physically active lifestyle, over 60% of American adults are insufficiently active to achieve these benefits and over 25% are not active at all in their leisure time.[14,15] Activity decreases with age and is less common among women than men and among those with lower income and less education. Data suggest that such community characteristics as proximity of recreation facilities; street design; housing density; and accommodation for safe pedestrian, bicycle, and wheelchair use play a significant role in promoting or discouraging physical activity.[16,17] A number of instruments have been developed to assess physical activity, such as the International Physical Activity Questionnaire,[18] although accurate measurement of physical activity levels in children is difficult. The National Center for Chronic Disease Prevention and Health Promotion at the CDC is currently developing a detailed research agenda on scientific and policy issues associated with promoting physical activity.

Measuring physical activity levels and contributory factors. Research question: What are the best objective measures of physical activity levels and how do they compare with self-reported measures in adults and in children? How do individuals perceive whether or not their environment encourages physical activity and how do those perceptions correlate with objective measures of the environment (such as percentage of

streets with sidewalks)? Do perceived or objective measures better predict physical activity behavior? What are the best measures of pedestrian and bicycling infrastructure and other environmental characteristics that facilitate physical activity? What community policies are best correlated with physical activity?

Research design: One could compare self-reported physical activity levels with those measured by the use of global positioning satellite and geographic information systems, as is being done in the SMARTRAQ project.[19] Environmental assessments could include gathering self-reported perceptions and measuring prevalence, quality, and use of recreational and transportation facilities such as walking trails, sidewalks, and bicycle paths.[20] Current projects supported by the Robert Wood Johnson Foundation on environmental factors and policies that influence physical activity may provide useful information on these research areas.[21]

Walking as an indicator of community health. Research question: Can observed levels of walking be used as an indicator of the physical and mental health of a community? After socioeconomic status and other factors are controlled for, do communities with high observed levels of walking have less obesity than those with low levels of walking? Can walking be used as a unifying theme for other realms of public health such as physical activity, safety, air pollution, and social capital?

Research design: In multiple neighborhoods or communities, one could measure walking, walkability,[22] overall physical activity levels, obesity, neighborhood satisfaction, social engagement, and other health measures to assess their associations while controlling for self-selection and other confounders.

Schools and Children

Recent reports have documented a substantial increase over the past decade in the proportion of US children and adolescents who are overweight.[23] These changes most likely result from decreased physical activity and increased dietary fat and calories, causes that are in turn influenced by the physical, social, and economic environment. Physical activity and nutrition habits established in childhood are likely to influence lifelong habits. The design of the built environment, especially distance and traffic hazards, influences whether a child will walk, bicycle, or be driven to school.[24]

Older urban community schools, rather than being renovated, are often abandoned in favor of larger new suburban schools located farther from community centers, further hindering children's ability to walk or bike.[25] Hazardous routes that prevent children from walking and bicycling to school can be improved when there are the resources and political will to make changes, such as those promoted by the Safe Routes to School initiative.[26]

The term "hazard busing" describes the use of school buses to transport children short distances from home to school to avoid unsafe road crossings and absent sidewalks. While the prevalence of hazard busing nationally is unknown, a South Carolina study found that students attending schools built after 1971 were 3 times more likely than those attending older schools to receive hazard busing.[27]

Types and determinants of travel to school. Research questions: What factors promote or hinder children's ability to walk or bicycle to school? What design characteristics of schools facilitate walking and biking? What policies, such as magnet schools, may lead to longer commutes to school? When did those policies go into effect and what was their impact on the prevalence of children walking and biking to school? Are there social benefits for children who are able to walk or bicycle to school? How prevalent is hazard busing and how do planners decide where it is needed? Is the prevalence of walking and bicycling among persons of all ages higher in communities with high rates of children walking and bicycling to school?

Research design: One could conduct cross-sectional surveys of schools to assess the relationships among walking and bicycling to school, obesity prevalence, hazard busing, school design, and environmental factors. Longitudinal studies would also be valuable; for example, Safe Routes to School programs and policy interventions could be evaluated in intervention and control communities by a multiple time series design.

Unintentional Injuries

Motor vehicle and pedestrian injury rates are associated with numerous environmental factors (including road design and traffic congestion) and with driver and pedestrian behaviors that result from these and other factors. A recent study reported an average annual traffic death rate that was over 50% higher in the nation's 10 most sprawling metropolitan areas than in the 10 least sprawling metropolitan areas.[5] Environments designed to encourage walking and bicycling contribute to lower pedestrian and bicyclist injury rates in Holland and Germany than in the United States.[28] Traffic-calming measures[29] and other improved road and trail designs that take into account potential conflicts between pedestrians, bicyclists, and motorists may lead to reductions in motor vehicle collisions and injuries.

Influence of community design on risk of injury. Research question: How do motor vehicle, pedestrian, and bicyclist injury rates differ between traditional suburbs and newer automobile-dependent suburbs, controlling for socioeconomic factors? How can community design elements predictive of lower injury rates in a neighborhood be identified and measured? How do these design features affect mobility and transportation choices for children and the elderly?

Research design: Ecological studies of injury rates in traditional neighborhoods, recently gentrified urban neighborhoods, and newer automobile-dependent suburbs with similar socioeconomic characteristics would be useful. Geographic information systems could be used to compare pedestrian, bicycle, and motor vehicle crashes in different neighborhoods or census tracts. Case–control studies could be used to identify specific community design factors associated with the occurrence of injuries. A cross-sectional survey of teenagers and elderly persons could be used to examine risk exposures and factors influencing their transportation choices.

Crime and Violence

Rates of crime and fear of crime are associated with features of the physical environment within neighborhoods.[30] Such features range from housing configurations that facilitate "eyes on the street" to abandoned buildings

that suggest vulnerability to crime. Little is known about how these factors interact with each other and with the larger social environment within neighborhoods to affect property crimes, violent crimes, and other social and health-related outcomes. In the 1970s, the strategy of Crime Prevention Through Environmental Design (CPTED), including design recommendations for housing layout, land use, territoriality, and physical maintenance, was developed to improve public safety.[31,32] Reductions in crime have been documented in communities that have followed CPTED recommendations.[33] Implementation of CPTED recommendations may have consequences on the health of a community beyond crime prevention, such as improvements in physical activity, mental health, and social capital.

Public health consequences of public safety design choices. Research question: Do specific CPTED design elements focused on public safety have secondary public health consequences? These consequences may be positive, such as fewer unintentional injuries, more physical activity, greater social capital, and lower rates of substance abuse, or negative, such as increased nonresidential land use, loss of community identity, and higher property values leading to less affordable housing. As a related question, how do walking patterns differ in communities with and without security gates?

Research design: A first step would be to collect qualitative data on public health consequences from focus groups of residents and service providers in communities where CPTED-related interventions have occurred. Next, quantitative research could be conducted to examine the prevalence of these consequences, the specific types of CPTED-related changes that contribute to them, and the subgroups of the population most affected. This research could include before-and-after data on a range of indicators from communities in which CPTED interventions have been implemented and similar comparison communities without such interventions.

Impact of Community Design on Persons With Disabilities

The design of the built environment has a substantial impact on the ability of persons with disabilities to be physically active, to use transportation systems, and to be socially integrated into their community.[6] Communities that have user-friendly transportation systems and are compact and walkable are more accessible for persons with disabilities, allowing them to participate more fully in the community by working, shopping, and living within the integrated setting. Persons who use wheelchairs and other mobility devices generally benefit whenever a community is made more walkable, as long as appropriate accommodations (such as curb cuts) are included in such community improvements. Elderly persons without disabilities may receive similar benefits in improved quality of life from community designs that aid persons with disabilities.[34]

Physical activity, mobility, and social integration in persons with disabilities. Research questions: What characteristics of community design facilitate or discourage physical activity (such as curb cuts and benches for resting) in persons with disabilities? What accommodations (such as bus wheelchair lifts) are needed to provide access to community transportation systems and better mobility for persons with disabilities and for the elderly? What characteristics of community design (such as broken sidewalks and poor street lighting) lead to fear of injury and vulnerability to crime and thereby limit mobility in persons with disabilities and in the elderly? What characteristics of community design encourage the social integration of persons with disabilities into community activities? What are the barriers to providing design features that improve physical activity, mobility, and social integration for persons with disabilities? What are the health consequences of isolation in persons with disabilities and in the elderly if they cannot drive?

Research design: A first step would be to collect, from the literature and from focus groups of persons with disabilities, qualitative information on community designs that help and hinder physical activity, mobility, and social integration for persons with disabilities, and collect qualitative information on barriers to implementing favorable designs.[35] A case–control study, involving active persons with disabilities as cases and inactive persons with disabilities as controls, may be useful to help identify design factors that facilitate physical activity. A quasi-experimental design could be used to document improvements in quality of life for persons with disabilities in communities with and without the favorable community designs, while considering self-selection biases.

Health Effects of Air and Water Pollution

Environmental pollution is a well-documented cause of human illness.[36,37] Sprawling developments are associated with increased automobile use and accompanying air pollution.[5,38,39] Poor air quality exacerbates[40] and may even cause asthma[41] and other respiratory diseases. Disruption of farmlands and forests and paving for new roads and parking reduce the ground's natural filtering capacity, causing increased siltation, runoff of pollutants from impervious surfaces, and reduced water quality. Bacterial, chemical, and sediment contamination of water supplies increases the cost of providing potable water to communities and may cause gastrointestinal and other diseases.

Influence of community design on emissions of overall and specific pollutants. Research questions: What tradeoffs in terms of criteria air pollutants, particulate matter, and airborne toxics are involved with land-use policies that promote increased density, walkability, and connectivity? For example, although higher density may reduce per capita vehicle emissions on a regional basis, it may create more traffic congestion and higher levels of different pollutants in the dense areas. How can these consequences be mitigated? How can environmental regulations be revised to encourage community designs that have lower air and water pollution levels? Does the opening or expansion of a mass transit system lead to a measurable change in air pollution levels?

Research design: Detailed data from urban planning and air monitoring could be used with geographic information system techniques to compare selected design characteristics with health outcomes in a group of older traditional suburbs and newer automobile-dependent suburbs. In addition, many metropolitan areas that have measured levels of air pollutants could be compared to determine which design characteristics (such as density) are associated with

lower levels of each air pollutant. In suburban and rural areas not served by public water systems, one could compare well water quality to land-use features such as lot size, road design, and separation of residential areas from agricultural and industrial areas.

Mental Health

The natural and built environment in which individuals or groups live can directly affect their mental health.[7] Positive effects of different types of natural environments such as green space include improved social and cognitive functioning and decreased violence.[42,43] Long commutes and traffic congestion may contribute to "road rage."[44]

Influence of physical setting characteristics on mental health. Research question: How do particular characteristics of a physical setting, such as noise level, crowding, crime, lighting, traffic, and green space, affect the mental health and social functioning of adults and children? How do these characteristics affect health in various physical settings, such as work, school, home, and during commuting? How do these characteristics affect health in persons at different life stages and in different social groups?

Research design: Cross-sectional surveys could be conducted in multiple communities to assess cognitive, social, and physical health in physical settings that have differing characteristics. In addition, a quasi-experimental design could be used to compare mental health in communities that have similar population characteristics but different physical settings. Investigators may be able to identify natural experiments in which they can assess the impact on mental health of some physical factors such as noise from roads and daylighting in buildings.

Social Capital

Social capital is defined as the social, political, and economic networks and interactions that inspire trust and reciprocity among citizens.[8] Social capital may be affected by the design of the physical environment; for example, persons with long commutes may have less time for civic engagement.[8] Persons with low social capital may be at increased risk for poor physical and mental health.[45,46]

Influence of built environment on social capital and health. Research question: What features of the built environment, such as front porches, sidewalks, parks, churches, community centers, and transportation alternatives, affect social capital in ways that in turn affect health?

Research design: Existing literature on the relationship of the built environment, social capital, and health could be reviewed, and cross-sectional, longitudinal, and quasi-experimental studies could be conducted in a variety of communities to further examine these issues. For example, after controlling for appropriate confounders, one could examine the differences in both community involvement and mental health among persons who spend the same amount of time in their commute to work but differ in whether their commute is made by walking, bicycling, using transit, carpooling, or driving alone.

Environmental Justice and Social Equity

Current patterns of urban development do not affect all populations equally. Persons with low incomes, minorities, children, the elderly, and persons with disabilities may suffer disproportionately from the adverse consequences of transportation and land-use decisions.[9] Many new communities, including some that incorporate many features of good design, do not accommodate these populations.

Characterizing social equity and health outcomes in relation to community design. Research questions: What is the impact of segregating people by life stage, income, ethnicity, disability status, or other demographic subgroup on health, well-being, and social capital? Does increased demand for well-designed urban housing lead to gentrification of older neighborhoods and decreased affordability of adequate housing[47] for low-income persons? What policies can protect low-income persons who are at risk of being displaced by urban renewal projects? Do the benefits of Smart Growth[48] accrue mainly to persons of high socioeconomic status?

Research design: Qualitative and quantitative case studies may be used to identify the impact on health of segregating persons by income and other characteristics. One could conduct a before-and-after study to assess whether an improved transportation system provided better access to jobs, medical care, and other necessities for low-income persons. Examples of mixed-income communities that have successfully incorporated Smart Growth principles may be valuable as best practices that could be replicated elsewhere.

Crosscutting Issues

Many design choices available to community planners and policymakers have the potential to improve the public's health in multiple ways. For example, changes in transportation policy can simultaneously improve air quality, increase physical activity, limit injury risks, facilitate mobility for persons with disabilities, and reduce social inequities.

Identifying useful case studies. Research question: What best practices about health and the built environment, including policies and environmental factors, can be identified from in-depth case studies of selected well-planned communities and of selected poorly designed communities? How do physical activity levels, transportation choices, air pollution levels, and health outcomes in conventional urban and suburban communities compare with those built in accordance with the principles of Smart Growth? What are the demographic characteristics, such as age, household structure, income, and race/ethnicity, of persons living in communities built in accord with Smart Growth principles compared with those living in other residential areas?

Research design: Case studies are valuable for describing processes and assessing the positive and negative impacts of design choices and policy interventions in individual communities[49]; results of such studies can help inform other communities that are facing similar decisions. Qualitative and longitudinal quasi-experimental studies could examine the health and behavior characteristics of residents in existing neighborhoods or communities before and after their renovation, as well as in selected neighborhoods or communities that represent good and poor design. Longitudinal studies can help overcome limitations associated with self-selection and financial considerations that influence where individuals choose to live.

Model codes and best practices in zoning and building requirements. Research question:

What types of enforceable building codes, zoning codes, parking regulations, and incentive/disincentive programs can be used to promote health and prevent disease and injury? What types of codes are more likely to lead to adverse health outcomes? For example, zoning codes that require a minimum number of parking spaces per housing unit but do not require sidewalks encourage automobile dependency and discourage walking. Zoning codes that restrict the use, storage, and transportation of hazardous materials near schools and residential areas may reduce the risk of toxic exposures. What model codes (such as the Smart Code[50]) already exist and how can one analyze model codes to assess their impacts on health?

Research design: The planning literature could be reviewed to identify model codes that promote healthy activities as well as codes that may serve as barriers to such activities. Selected health outcomes in communities that have adopted model codes and incentive programs could be compared with outcomes in communities that have less progressive codes. The social and political circumstances that lead a community to update its codes and to adopt or not adopt a model code also could be examined.

Health impact assessment of community design choices. A health impact assessment is an estimate of the effects of a specified action on the health of a defined population in order to improve the quality of public policy decision-making from a health perspective. Modeled in part on the concept of an environmental impact statement,[51] a health impact assessment could provide guidance to decisionmakers on the impact of a proposed project on physical activity, air and water pollution, mobility for persons with disabilities, mental health, social capital, and environmental justice. A health impact assessment may be more acceptable to the development community if it is created as a set of guidelines rather than as regulations. Research question: How could health impact assessments be incorporated into community design processes?

Research design: A pilot health impact assessment process could be developed from a literature review and with advice from a group of experts from relevant disciplines. One could then create and evaluate demonstration projects in several communities in which there are cooperative planning and public health staff. The health impact assessment processes used in the United Kingdom[52] could help guide such demonstration projects.

Effective communications strategies to distill research results into a practical form. Research question: What are the most effective strategies to communicate research findings about the health effects of community design processes to specific audiences such as policymakers, planners, bankers, community residents, and children?

Research design: For each target audience, appropriate communication strategies could be developed and tested with assistance from behavioral scientists and social marketers.

Market research to better understand how to motivate change. Research question: What are the perceived benefits and barriers to choosing healthier community designs from the perspective of the general public, planners, developers, and public officials? How can a better understanding of these perceptions be used to develop design recommendations that appeal to these target groups?

Research design: One could conduct market research with the target groups on the perceived benefits and barriers to choosing healthier community designs. The results could be used to stimulate market demand for such designs.[53]

Catalysts to increase likelihood that design changes have desired health impact. Research question: For specific physical design interventions to have the desired health outcomes, what catalysts or other conditions, such as active neighborhood groups, cohesiveness, high social capital, or health promotion services, must exist simultaneously? For example, building a sidewalk may or may not lead to increased physical activity, depending on other neighborhood characteristics such as perceived safety and proximity and connectedness to desirable destinations.

Research design: The implementation of selected interventions, such as building sidewalks or installing a new transit system, could be compared in multiple communities to assess other factors that influence the health impact of those interventions. From such studies, one could better understand the barriers to obtaining benefits from such changes and make recommendations on how to optimize the health benefits of such interventions.

DISCUSSION

While some background research has been done on almost all topics described in this report, further investigation of these questions would contribute to a fuller understanding of the relationship between health and the built environment. It is likely that there are other important research topics not considered here that should be added in future years.

As a next step, a process should be established to set priorities among the many topics described earlier and in Table 1. Setting such priorities requires balancing issues such as technical feasibility, availability of funding, and potential health impact.

Research on health and the built environment requires the collaboration of investigators from a variety of professional disciplines, including some who have not previously interacted with the public health community. Interdisciplinary conferences[54,55] are valuable for building ties among potential collaborators. Support for research may come from many sources, including federal government agencies (e.g., the CDC, National Institutes of Health, Environmental Protection Agency), private foundations (e.g., Robert Wood Johnson Foundation), professional associations (e.g., American Planning Association, Urban Land Institute), and industry groups (e.g., National Association of Home Builders). In addition, interested community groups may conduct local studies that have national implications.

A wide range of types of quantitative and qualitative studies[49,56] would be useful to help answer the questions raised in this research agenda. The choice of study design will depend on many factors, including the questions being asked, the ability to measure relevant variables, the availability of data and resources, and even the creativity of the investigators. For example, valuable information was obtained from a natural experiment in which investigators observed that pediatric asthma emergency events decreased significantly when motor vehicle traffic and air pollution levels declined during the 1996 Summer Olympics.[40]

Although it may be easier to design and conduct small studies on the specific topics included in this report, consideration should also be given to the development of a few large integrated studies that would examine multiple outcomes simultaneously in a number of types of urban and suburban communities. After assessing community characteristics such as sidewalks, transportation mode options, automobile usage, air pollution levels, connectivity, school accessibility, housing quality, and mixed-use design, investigators could measure corresponding health outcomes, including rates of physical activity, obesity, asthma, injury, and crime, as well as indicators of mental health, social capital, and social equity. Such large integrated studies would be valuable for documenting for policymakers the influence of good community design features on multiple health outcomes.

Two limitations should be considered in reviewing the topics presented in this research agenda. First, as in any process of expert decisionmaking, the ideas generated depended on the individuals invited to and participating in the workshop. A different group of participants may have generated a different list of research topics. We hope the publication of these results will stimulate other colleagues to identify and circulate other research topics and methods; this will result in a more robust research agenda and ultimately in more useful information on the association between health and the built environment.

Second, in a process such as the one described here, participants provide research ideas that are generally focused in their fields of expertise. This is appropriate as a means of launching specific research projects; however, such ideas may be disconnected and lack a unifying theoretical basis or empirical cross-linkages. In a complex area such as the interface of health and the built environment, theoretical approaches such as ecological models[57,58] and syndemic analysis[59] may help synthesize and systematize research data from different lines of research.

Results of the research described in this report may help identify best practices and help communities to avoid making design decisions that have unintended negative consequences. Research results are important both for the design of new communities and for the revitalization of existing communities. Overall, it is hoped that such research will help guide local community design decisions and favorably influence the health of the public. ■

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References

1. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002;117:201–217.

2. World Health Organization. WHO Definition of Health. New York, NY: World Health Organization; 1948. Available at: http://www.who.int/about/definition/en. Accessed April 22, 2003.

3. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002; 23(2 suppl):64–73.

4. National Task Force on the Prevention and Treatment of Obesity. Overweight, obesity, and health risk. *Arch Intern Med.* 2000;160:898–904.

5. Ewing R, Pendall R, Chen D. Measuring sprawl and its impact. Smart Growth America. 2002. Available at: http://www.smartgrowthamerica.org/sprawlindex/sprawlindex.html. Accessed April 22, 2003.

6. World Health Organization. International classification of functioning, disability, and health. Available at: http://www3.who.int/icf/icftemplate.cfm. Accessed April 22, 2003.

7. Evans GW. The built environment and mental health. *J Urban Health.* In press.

8. Putnam RD. *Bowling Alone: The Collapse and Revival of American Community.* New York, NY: Simon and Schuster; 2000.

9. Bullard RD, Johnson GS, eds. *Just Transportation: Dismantling Race and Class Barriers to Mobility.* Gabriola Island, British Columbia: New Society Publishers; 1997.

10. Lopez R, Hynes HP. Sprawl in the 1990s: measurement, distribution, and trends. *Urban Aff Rev.* 2003;38:325–355.

11. Leadership in Energy and Environmental Design Green Building Rating System for New Construction and Major Renovations. Version 2.1. Washington, DC: US Green Building Council; 2003. Available at: http://www.usgbc.org/LEED/LEED_main.asp. Accessed June 24, 2003.

12. 28 CFR Part 36: ADA Standards for Accessible Design. Washington, DC: US Dept of Justice; 1994. Available at: http://www.usdoj.gov/crt/ada/stdspdf.htm. Accessed June 24, 2003.

13. Briss PA, Zaza S, Pappaioanou M, et al. Developing an evidence-based guide to community preventive services—methods. *Am J Prev Med.* 2000;18(1 suppl): 35–43. Available at: http://www.thecommunityguide.org. Accessed April 22, 2003.

14. *Physical Activity and Health: A Report of the Surgeon General.* Washington, DC: Dept of Health and Human Services; 1996.

15. Centers for Disease Control and Prevention. Physical activity trends—United States, 1990–1998. *MMWR Morb Mortal Wkly Rep.* 2001;50:166–169.

16. Frank LD, Engelke PD. The built environment and human activity patterns: exploring the impacts of urban form on public health. *J Plann Lit.* 2001;16: 202–218.

17. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity: a systematic review. *Am J Prev Med.* 2002;22(4 suppl):73–107.

18. International Physical Activity Questionnaire Committee. International Physical Activity Questionnaire. 2002. Available at: http://www.ipaq.ki.se. Accessed April 22, 2003.

19. Georgia Institute of Technology. Strategies for Metropolitan Atlanta's Regional Transportation and Air Quality (SMARTRAQ). Available at: http://www.smartraq.net/about.htm. Accessed April 22, 2003.

20. Pikora TJ, Bull FCL, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable audit instrument to measure the physical environment for physical activity. *Am J Prev Med.* 2002;23:187–194.

21. Robert Wood Johnson Foundation. Active Living Policy and Environmental Studies. Available at: http://www.alpes.ws. Accessed April 22, 2003.

22. Safe Routes to School Sacramento. Walkability checklist. Available at: http://www.saferoutessac.org/walk.pdf. Accessed April 22, 2003.

23. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA.* 2002;288:1728–1732.

24. Centers for Disease Control and Prevention. Barriers to children walking and biking to school—United States, 1999. *MMWR Morb Mortal Wkly Rep.* 2002;51:701–704.

25. National Trust for Historic Preservation. Historic neighborhood schools in the age of sprawl: why Johnny can't walk to school. 2000. Available at: http://www.nthp.org/issues/historic_schools.html. Accessed April 22, 2003.

26. Marin County Bicycle Coalition. Safe Routes to School. Available at: http://www.saferoutestoschools.org. Accessed April 22, 2003.

27. Kouri C. *Wait for the Bus: How Lowcountry School Site Selection and Design Deter Walking to School and Contribute to Urban Sprawl.* Charleston: South Carolina Coastal Conservation League; November 1999.

28. Pucher J, Dijkstra L. Promoting safe walking and cycling to improve public health: lessons from The Netherlands and Germany. *Am J Public Health.* 2003;93:1509–1516.

29. Elvik R. Area-wide urban traffic calming schemes: a meta-analysis of safety effects. *Accid Anal Prev.* 2001;33:327–336.

30. Taylor RB, Harrell AV. Physical environment and crime. National Institute of Justice Research Report; May 1996. Available at: www.ncjrs.org/txtfiles/physenv.txt. Accessed April 22, 2003.

31. Michael S. International clearinghouse on crime prevention through environmental design. Available at: http://www.thecptedpage.wsu.edu. Accessed April 22, 2003.

32. Mair JS, Mair M. Violence prevention and control through environmental modifications. *Annu Rev Public Health.* 2003;24:209–225.

33. Carter SP, Carter SL, Dannenberg AL. Zoning out crime and improving community health in Sarasota, Florida: "crime prevention through environmental design." *Am J Public Health.* 2003;93:1442–1445.

34. Pollak PB. Liveable communities: an evaluation guide. 1999. Available at: http://research.aarp.org/consume/d16905_communities.html. Accessed April 22, 2003.

35. Center for Outcome Measurement in Brain Injury. Craig Hospital Inventory of Environmental Factors (CHIEF). Englewood, Colo. 2001. Available at: http://www.tbims.org/combi/chief. Accessed April 22, 2003.

36. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution. *Am J Respir Crit Care Med.* 1996;153:3–50.

37. Committee of the Environmental and Occupational Health Assembly of the American Thoracic Society. Health effects of outdoor air pollution: part 2. *Am J Respir Crit Care Med.* 1996;153:477–498.

38. Frank LD, Stone B Jr, Bachman W. Linking land use with household vehicle emissions in the central Puget Sound: methodological framework and findings. *Transportation Res Part D.* 2000;5:173–196.

39. Holtzclaw J, Clear R, Dittmar H, Goldstein D, Haas P. Location efficiency: neighborhood and socioeconomic characteristics determine auto ownership and use—studies in Chicago, Los Angeles and San Francisco. *Transportation Plann Technol.* 2002;25:1–27.

40. Friedman MS, Powell KE, Hutwagner L, Graham LM, Teague WG. Impact of changes in transportation and commuting behaviors during the 1996 Summer Olympic Games in Atlanta on air quality and childhood asthma. *JAMA.* 2001;285:897–905.

41. McConnell R, Berhane K, Gilliland F, et al. Asthma in exercising children exposed to ozone: a cohort study. *Lancet.* 2002;359:386–391.

42. Kuo FE, Sullivan WC. Environment and crime in the inner city: does vegetation reduce crime? *Environ Behav.* 2001;33:343–367.

43. Taylor AF, Kuo FE, Sullivan WC. Coping with ADD: the surprising connection to green play settings. *Environ Behav.* 2001;33:54–77.

44. National Highway Traffic Safety Administration. National survey of speeding and other unsafe driving actions. Volume II: driver attitudes and behavior. Available at: http://www.nhtsa.dot.gov/people/injury/aggressive/unsafe/att-beh/Chapt1-2.html. Accessed April 22, 2003.

45. Kawachi I. Social capital and community effects on population and individual health. *Ann N Y Acad Sci.* 1999;896:120–130.

46. Hawe P, Shiell A. Social capital and health promotion: a review. *Soc Sci Med.* 2000;51:871–885.

47. Matte TD, Jacobs DE. Housing and health—current issues and implications for research and programs. *J Urban Health.* 2000;77:7–25.

48. Smart Growth Network. About smart growth. 2002. Available at: http://www.smartgrowth.org/about/default.asp. Accessed April 22, 2003.

49. Yin RK. *Case Study Research: Design and Methods.* 2nd ed. Thousand Oaks, Calif: Sage Publications; 1994.

50. Duany Plater-Zyberk & Company. Smart code. Available at: http://www.smartcode.org. Accessed April 22, 2003.

51. Norfolk International Airport new runway environmental impact statement. Available at: http://www.norfolkairport.com/eis. Accessed April 22, 2003.

52. International Health Impact Assessment Consortium. What is health impact assessment? Available at: http://www.ihia.org.uk/abouthia.html. Accessed April 22, 2003.

53. Maibach EW. Recreating communities to support active living: a new role for social marketing. *Am J Health Promot.* 2003;18(1):114–119.

54. Local Government Commission. 2nd Annual New Partners for Smart Growth: Building Safe, Healthy, and Livable Communities Conference. New Orleans, 2003. Available at: http://www.outreach.psu.edu/C&I/SmartGrowth. Accessed April 22, 2003.

55. Robert Wood Johnson Foundation. Active Living Network Conference. Boulder Colo, 2002. Available at: http://www.activeliving.org/network_conference.htm. Accessed April 22, 2003.

56. Brownson RC, Petitti DB, eds. *Applied Epidemiology: Theory to Practice.* New York, NY: Oxford University Press; 1998.

57. Sallis JF, Owen N. Ecological models. In: Glanz K, Lewis FM, Rimer BK, eds. *Health Behavior and Health Education.* 2nd ed. San Francisco, Calif: Jossey-Bass Publishers; 1997:403–424.

58. Institute of Medicine, Board on Health Promotion and Disease Prevention. *Who Will Keep the Public Healthy? Educating Public Health Professionals for the 21st Century.* Washington, DC: National Academies Press; 2003.

59. Centers for Disease Control and Prevention. Spotlight on syndemics. Available at: http://www.cdc.gov/syndemics. Accessed April 22, 2003.

Promoting Safe Walking and Cycling to Improve Public Health: Lessons From The Netherlands and Germany

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Objectives. We examined the public health consequences of unsafe and inconvenient walking and bicycling conditions in American cities to suggest improvements based on successful policies in The Netherlands and Germany.

Methods. Secondary data from national travel and crash surveys were used to compute fatality trends from 1975 to 2001 and fatality and injury rates for pedestrians and cyclists in The Netherlands, Germany, and the United States in 2000.

Results. American pedestrians and cyclists were much more likely to be killed or injured than were Dutch and German pedestrians and cyclists, both on a per-trip and on a per-kilometer basis.

Conclusions. A wide range of measures are available to improve the safety of walking and cycling in American cities, both to reduce fatalities and injuries and to encourage walking and cycling. (*Am J Public Health.* 2003;93:1509–1516)

Improving conditions for walking and bicycling in our cities is vital for America's public health. The measures described in this article would not only reduce pedestrian and cycling fatalities and injuries but also allow millions of people, many of them dangerously overweight, to bike or walk for some of their short trips and thus obtain healthful exercise in the course of daily life. More walking and cycling would yield further public health benefits by reducing the use of automobiles, thus diminishing air and noise pollution and the overall level of traffic danger.

The United States is gripped by a worsening epidemic of obesity. Nationwide surveys based on self-reported weight and height indicate an increase in obesity from 12% of adults in 1991 to 20% in 2000.[1] Estimates of obesity based on clinical measurements of weight and height are considerably higher, indicating that in 2000, 31% of the adult population was obese (body mass index [BMI] ≥ 30) and 64% was overweight (BMI ≥ 25).[2] Many studies suggest that lack of physical exercise is one important reason for the alarming trend toward increased obesity. Several articles and editorials in the leading medical and public health journals have explicitly advocated more walking and cycling for daily travel as the most affordable, feasible, and dependable way for people to get the additional exercise they need.[3–7] Similarly, the US surgeon general specifically recommends more walking and cycling for practical, daily travel as an ideal approach to raising physical activity levels.[8]

Even in the sprawling metropolitan areas of the United States, 41% of all trips in 2001 were shorter than 2 miles, and 28% were shorter than 1 mile.[9] Bicycling can easily cover distances of up to 2 miles, and most people can walk at least a mile.[10] Yet Americans use their cars for 66% of all trips up to a mile long and for 89% of all trips between 1 and 2 miles long.[9] Clearly, there is enormous potential for increased walking and cycling over these shorter trip distances.

There are 2 problems with proposals to increase walking and cycling: their current danger and inconvenience in most American cities. As documented in this article, walking and cycling in the United States are much more dangerous than car travel, both on a per-trip and per-mile basis. Moreover, the lack of proper pedestrian and bicycling facilities makes walking and cycling not only unsafe but also inconvenient, slow, unpleasant, and unfeasible in most places.

The good news presented in this article is that it is indeed possible to achieve safe and convenient walking and cycling conditions, as demonstrated by the experience of Germany and The Netherlands. Those 2 countries have implemented a wide range of policies over the past 2 decades that have simultaneously encouraged walking and cycling while dramatically lowering pedestrian and bicyclist fatalities and injuries and keeping auto use at only half the American level. The Netherlands and Germany provide valuable lessons for integrating more physical exercise into the lives of Americans.

This article first examines variations in walking and cycling levels among North American and Western European countries and then focuses on The Netherlands, Germany, and the United States in particular. We examine differences in travel behavior, fatality and injury rates, and trends over time. Most importantly, we describe the 6 categories of policies in The Netherlands and Germany that have made walking and cycling such safe and attractive alternatives to driving: better facilities for walking and cycling, urban design sensitive to the needs of nonmotorists, the traffic calming of residential neighborhoods, restrictions on motor vehicle use in cities, rigorous traffic education of both motorists and nonmotorists, and strict enforcement of traffic regulations protecting pedestrians and bicyclists.

DATA AND METHODS

We relied on secondary sources for all the data series discussed in this article. They are the official national sources of statistics on travel behavior and traffic accidents in each country. For the United States, the data for travel behavior came from the 1995 Nationwide Personal Transportation Survey and the 2001 National Household Travel Survey, both conducted by the US Department of Transportation (Federal Highway Administration).[11] The data on traffic fatalities also came from the US Department of Transportation (National Highway Traffic Safety Administration),[12] while the injury data came

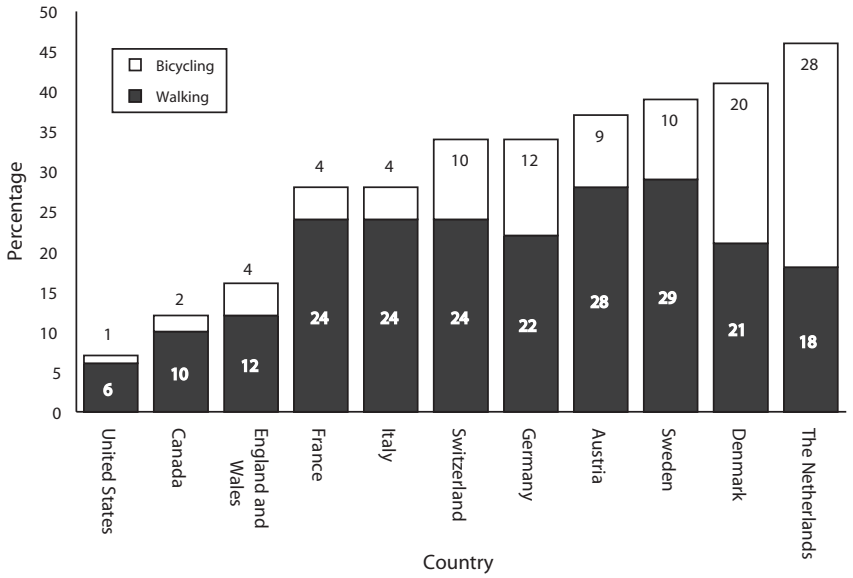
from the Centers for Disease Control and Prevention (CDC).[13]

For Germany, the data on travel behavior came from the German Ministry of Transport[14,15] and the German Institute of Economic Research.[16] The German fatality and injury data came from the Federal Statistical Office[17] and the Federal Traffic Institute.[18]

The data for The Netherlands came from Statistics Netherlands[19] and the Dutch Ministry of Transport.[20] Each of these surveys and other data collection procedures relied on extensive underlying methodologies that cannot be discussed here. Interested readers can consult any of the individual sources for detailed information. We note in the text and figures the specific sources and any important differences among the countries in definition or methods.

Some of these data series are more comparable across countries than others. The travel surveys measuring usage of different means of transportation rely on basically the same definitions of transport modes but use varying methodologies for sampling and trip measurement. The data on traffic fatalities are quite reliable. Studies indicate that roughly 95% of all traffic fatalities are reported to the police and thus appear in official records.[21] Moreover, all the countries that we examined define traffic fatalities as occurring within 30 days of the crash.

Traffic injury data are far less comparable. Underreporting of pedestrian and cyclist injuries is a problem in all countries. For the United States, we used the CDC injury estimates from WISQARS, which are based on a representative survey of injuries reported by hospital emergency rooms.[13] Even those estimates underreport total injuries since they exclude minor injures not requiring a hospital visit. The Dutch and German injury estimates are based on police reports. One study estimated that Dutch police reports captured only 15% of minor injuries to pedestrians and cyclists but 60% of all injuries requiring a hospital visit.[22] German police reports captured 16% of minor injuries but 48% of injuries requiring a hospital visit.[21] Thus, the Dutch and German estimates of injuries should be roughly doubled to make them comparable to the hospital-based injury estimates of the CDC.



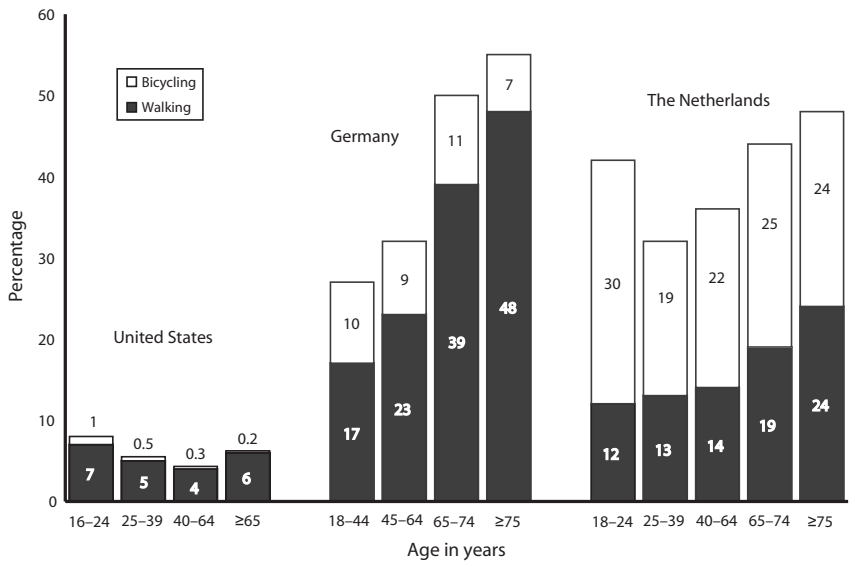
Note. Modal split distributions for different countries are not fully comparable owing to differences in trip definitions, survey methodologies, and urban area boundaries. The distributions given here are intended to show the approximate differences among countries and should not be used for exact comparisons.
Source. Transportation Research Board,[29] Table 2-2, p. 30.

FIGURE 1—Percentage of trips in urban areas made by walking and bicycling in North America and Europe, 1995.

VARIATION AMONG COUNTRIES IN LEVELS OF WALKING AND CYCLING

Unfortunately, trends in travel behavior in the United States could hardly be worse for public health. The journey-to-work section of the US Census indicates that the percentage of all work trips made by walking fell from 10.3% in 1960 to only 2.9% in 2000.[23] Including all trip purposes, the Nationwide Personal Transportation Survey shows that the percentage of urban trips made by walking and cycling fell from 10.0% in 1977 to only 6.3% in 1995, which is far lower than in most other countries.[9,10] Figure 1 shows the percentage of all urban trips made in 1995 by walking and cycling in the United States, Canada, and 9 European countries.[24] Even Canada has almost twice the percentage of walk and bike trips as in the United States. In most European countries, at least a fourth of urban trips are made by walking or cycling, and a few countries—like Denmark and The Netherlands—report a nonmotorized travel rate of over 40%.

Perhaps even more striking are the large differences in travel behavior between countries as their populations get older. As shown in Figure 2, walking increases with age in both The Netherlands and Germany, while cycling falls off only slightly. Indeed, the Dutch and Germans who are 75 and older make roughly half their trips by foot or bike, compared with only 6% of Americans aged 65 and older. While cycling is almost nonexistent among the American elderly, it accounts for a fourth of all trips made by the Dutch elderly and for 7% of trips made by the German elderly. Equally stunning, walking accounts for 48% of trips by Germans aged 75 and older and 24% of trips made by Dutch aged 75 and older. This not only provides them with valuable physical exercise but also ensures them a level of mobility and independence that greatly enhances their quality of life. It also may contribute to both the longer life expectancy and the longer healthy life expectancy in the Netherlands and Germany—2 years longer than in the United States.[25] As the Dutch and German examples clearly show, the physical and men-



Source. US Department of Transportation,[11] German Ministry of Transport,[14,15] and Statistics Netherlands.[19]

FIGURE 2—Percentage of trips in urban areas made by walking and bicycling in the United States, Germany, and The Netherlands, by age group, 1995.

tal limitations that come with aging are not the main impediments to walking and cycling by the American elderly.

For both the elderly and the nonelderly, walking and cycling are discouraged in the United States by longer trip distances, the low cost and ease of auto ownership and use, and a range of other public policies that make walking and cycling inconvenient, unpleasant, and, above all, unsafe.

The more compact land-use patterns in European cities lead to average trip distances that are only about half as long as in American cities and thus are easier to cover by foot or by bike.[26] As explained in previous studies[27] and by other articles in this issue, planning for more compact, mixed-use development in American cities would enhance the feasibility of walking and cycling by reducing trip distances to likely destinations. However, that is a long-term approach that will take many years to implement, if it can be adopted at all. Moreover, as noted earlier, 41% of all urban trips in the United States are already shorter than 2 miles, and 28% are shorter than 1 mile. The potential for more walking and cycling already exists. Thus, the extraordinarily low 6% of trips made by walking or cycling in American cities cannot be attributed mainly to long trip distances.[28] Indeed, if distance were the overriding factor, one might expect more cycling than walking in American cities, since cycling covers longer distances faster and easier. In fact, walk trips outnumber bike trips 6 to 1.

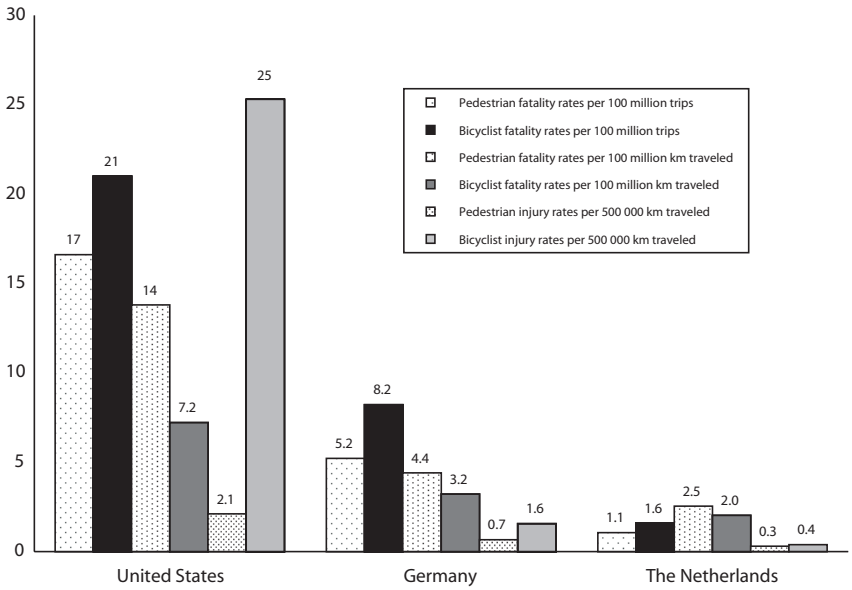
The much higher cost of auto ownership and use in Europe also helps explain the higher levels of walking and cycling there. High taxes on gasoline and new cars, as well as higher prices for parking, make the overall cost of auto use at least double what it is in the United States.[29] In addition, roadway and parking facilities are much more limited than in American cities. From a political perspective, it has been very difficult to raise taxes on auto ownership and use in the United States, even slightly, let alone to the dramatically higher levels in Europe. With over 95% of all parking free of charge, and with gasoline taxes, roadway tolls, licensing fees, and vehicle taxes among the lowest in the developed world, the United States makes driving a car almost irresistible.[29] That, in turn, discourages walking and cycling.

Clearly, however, one of the biggest impediments to more walking and cycling is the appallingly unsafe, unpleasant, and inconvenient conditions faced by pedestrians and bicyclists in most American cities. As shown in the next section, the perceived risk of walking and cycling in American cities is based on real dangers. Even without dramatic changes in American land-use and transportation systems, much could be done in the short term to improve walking and cycling conditions to make them both safer and more attractive.

DANGERS OF WALKING AND CYCLING IN THE UNITED STATES

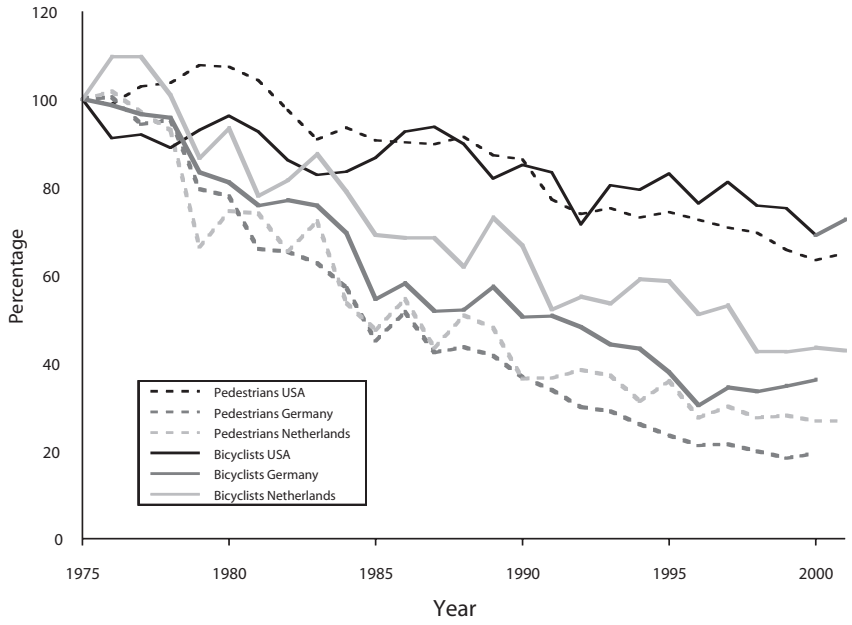
It is much more dangerous to walk or cycle in American cities than to travel by car. Per kilometer traveled, pedestrians were 23 times more likely to get killed than car occupants in 2001 (140 vs 6 fatalities per billion kilometers), while bicyclists were 12 times more likely than car occupants to get killed (72 vs 6 fatalities per billion kilometers).[30] Walking and cycling in American cities are much more dangerous than in many other countries. As shown in Figure 3, nonmotorist fatality rates in the United States are much higher than in The Netherlands and Germany. Per kilometer and per trip walked, American pedestrians are roughly 3 times more likely to get killed than German pedestrians and over 6 times more likely than Dutch pedestrians. Per kilometer and per trip cycled, American bicyclists are twice as likely to get killed as German cyclists and over 3 times as likely as Dutch cyclists.

Because of the unreliability of injury data in all countries, it is far more difficult to compare differences in pedestrian and cyclist injury rates. Nevertheless, they also appear to be much higher in the United States than in The Netherlands or Germany. The CDC data based on hospital reports capture a larger percentage of total injuries than the Dutch and German injury data, which are based on police reports. As noted earlier, studies indicate that the Dutch and German police reports capture only about half of all serious injuries requiring hospitalization.[21,22] Thus, the Dutch and German injury rates shown in Figure 3 should be roughly doubled to make them more comparable to the CDC rates for the United States. Even after



Source. US Department of Transportation[11,12]; Centers for Disease Control and Prevention[13]; German Institute of Economic Research[16]; German Federal Statistical Office[17]; German Federal Traffic Institute[18]; Statistics Netherlands[9]; and Dutch Ministry for Transport, Public Works and Water Management.[20]

FIGURE 3—Pedestrian and bicycling fatality rates and nonfatal injury rates in the United States, Germany, and The Netherlands, 2000.



Source. US Department of Transportation[12]; German Federal Statistical Office[17]; German Federal Traffic Institute[18]; Statistics Netherlands[19]; and Dutch Ministry for Transport, Public Works and Water Management.[20]

FIGURE 4—Trends in pedestrian and bicycling fatalities in the United States, Germany, and The Netherlands, 1975–2001 (1975 = 100%).

such an upward adjustment, American pedestrians are about twice as likely to get injured as German pedestrians and 4 times as likely as Dutch pedestrians. American cyclists are at even greater risk: they are 8 times more likely to get injured than German cyclists and about 30 times more likely than Dutch cyclists.

Some good news to offset that bad news is that a great deal could be done to make walking and cycling safer in the United States. Germany and The Netherlands, for example, have drastically cut the number of pedestrian and bicyclist deaths over the past 25 years by implementing a wide range of policies to improve safety. Figure 4 shows that from 1975 to 2001, total pedestrian fatalities declined by 82% in Germany and by 73% in The Netherlands. Over the same period, cyclist fatalities declined by 64% in Germany and by 57% in The Netherlands. The drop in cyclist fatalities in Germany is especially impressive because it came during a boom in cycling there, with a doubling in the number of bike trips and 50% growth in the share of total trips made by bike.[10] By contrast, the 27% fall in cyclist fatalities in the United States was due almost entirely to the sharp decline in cycling by children.[31,32]

HOW TO MAKE WALKING AND CYCLING SAFER

However dangerous walking and cycling currently are in the United States, it is definitely possible, and essential, to make them much safer. As shown by the wide range of coordinated policies in The Netherlands[33,34] and Germany,[35] the necessary techniques and programs already exist and have been proven to work extremely well. They include better facilities for walking and cycling, traffic calming of residential neighborhoods, urban design sensitive to the needs of nonmotorists, restrictions on motor vehicle use in cities, rigorous traffic education of both motorists and nonmotorists, and strict enforcement of traffic regulations protecting pedestrians and bicyclists. American cities lack only the political will to adopt the same strategies.

Owing to space limitations, we can only briefly summarize here the 6 categories of

public policy measure implemented in The Netherlands and Germany. For detailed descriptions and illustrations of the Dutch and German measures, readers can consult a range of publications about walking and cycling in Europe.[10,26,36–39]

Better Facilities for Walking and Cycling

One emphasis of Dutch[40] and German[35] policy has been to improve the transportation infrastructure used by pedestrians and bicyclists. For pedestrians, that has included extensive auto-free zones that cover much of the city center; wide, well-lit sidewalks on both sides of every street; pedestrian refuge islands for crossing wide streets; clearly marked zebra crosswalks, often raised and with special lighting for visibility; and pedestrian-activated crossing signals, both at intersections and midblock crosswalks.

Dutch and German cities also have invested heavily to expand and improve bicycling facilities. From 1978 to 1996, the Dutch more than doubled the extent of their already massive network of bike paths and lanes (from 9282 km to 18 948 km). From 1976 to 1995, the Germans almost tripled the extent of their bikeway network (from 12 911 km to 31 236 km).[10] In addition, there are an increasing number of so-called "bicycle streets," where cars are permitted but cyclists have strict right-of-way over the entire breadth of the roadway. Unlike the sparse and fragmented cycling facilities in the United States, the bike paths, lanes, and streets in The Netherlands and Germany form a truly coordinated network covering both rural and urban areas. Importantly, Dutch and German bikeway systems serve practical destinations for everyday travel, not just recreational attractions, as with most bike paths in the United States.

The provision of separate rights-of-way is complemented by various other measures: special bike turn lanes leading directly to intersections, separate bike traffic signals with advance green lights for cyclists, bicyclist-activated traffic signals at key intersections, and modification of street networks to create deliberate dead ends and slow, circuitous routing for cars but direct, fast routing for bikes.[10]

Traffic Calming of Residential Neighborhoods

Traffic calming limits the speeds of motor vehicle traffic, both by law—30 km per hour (19 mph) or less—and through physical barriers such as raised intersections and crosswalks, traffic circles, road narrowing, zigzag routes, curves, speed humps, and artificial dead ends created by midblock street closures.[10] Traffic calming gives pedestrians, bicyclists, and playing children as much right to use residential streets as motor vehicles; indeed, motor vehicles are required to yield to these other users. In both The Netherlands[41] and Germany, traffic calming is area-wide and not for isolated streets. That ensures that faster through traffic gets displaced to arterial routes designed to handle it and not simply shifted from one local road to another.

The most important safety impact of traffic calming is the reduced speeds of motor vehicles. This is crucial not only to the motorist's ability to avoid hitting pedestrians and bicyclists but also to the survival of nonmotorists in a crash. The British Department of Transport, for example, found that the risk of pedestrian death in crashes rises from 5% at 20 mph to 45% at 30 mph and 85% at 40 mph.[42]

Area-wide traffic calming in Dutch neighborhoods has reduced traffic accidents by 20% to 70%.[43] Traffic calming in German neighborhoods has reduced traffic injuries overall by 20% to 70% and serious traffic injuries by 35% to 56%.[44] A comprehensive review of traffic calming impacts in Denmark, Great Britain, Germany, and The Netherlands found that traffic injuries fell by an average of 53% in traffic-calmed neighborhoods.[45] In short, traffic calming greatly reduces the danger of traffic deaths and injuries in residential neighborhoods. Traffic calming greatly improves not only pedestrian safety but also the safety of bicycling, since much bike use—especially by children—is in residential neighborhoods.

Urban Design Oriented to People and Not Cars

New suburban developments in The Netherlands and Germany are designed to provide safe and convenient pedestrian and bicycling access.[10] Residential developments almost always include other uses such as cultural centers, shopping, and service establishments that can easily be reached by foot or bike. Both residential and commercial developments have sidewalks and bicycle paths to serve nonmotorists. Parking lots almost never surround buildings, as in the United States; instead, they are built next to or behind buildings, thus permitting easy access to pedestrians and bicyclists. When an obstacle such as a highway, railroad, or river must be traversed, Dutch and German cities usually provide safe and attractive pedestrian and bicyclist crossings. By comparison, strip malls in American suburbs are difficult and dangerous to reach by foot or bicycle, and most bridges lack provisions for pedestrians and bicyclists.

In the United States, the separation of residential from commercial land uses increases trip distances and makes the car a necessity. Suburban cul-de-sacs further discourage walking and bicycling by making trips circuitous and excessively long. Residential roads often feed directly into high-speed traffic arteries, increasing the danger of any trips outside the neighborhood. The lack of sidewalks in most American suburbs further exacerbates the problem.

Restrictions on Motor Vehicle Use

Dutch and German cities restrict auto use not only through traffic calming, auto-free zones, and dedicated rights-of-way for pedestrians and cyclists.[10,26,29] They also enforce lower general speed limits for motor vehicles in cities—usually 50 km per hour (31 mph). Parking is much more limited and more expensive than in American cities. In addition, most Dutch and German cities prohibit truck traffic and through traffic of any kind in residential neighborhoods. Motor vehicle turn restrictions are widespread; moreover, right turns on red are illegal.

Traffic Education

Driver training for motorists in The Netherlands and Germany is much more extensive, thorough, and expensive than in the United States.[46,47] A crucial aspect of that training in The Netherlands and Germany is the need to pay special attention to avoiding collisions with pedestrians and cyclists. Motorists are required by law to drive in a way

that minimizes the risk of injury for pedestrians and cyclists even if they are jaywalking, cycling in the wrong direction, ignoring traffic signals, or otherwise behaving contrary to traffic regulations.

Traffic education of children has high priority in both The Netherlands and Germany.[46,47] By the age of 10, all schoolchildren have received extensive instruction on safe walking and bicycling practices. They are taught not just the traffic regulations but how to walk and bicycle defensively, to anticipate dangerous situations, and to react appropriately. That sort of safety education is completely lacking in the United States.

Traffic Regulations and Enforcement

Traffic regulations in Germany and The Netherlands strongly favor pedestrians and bicyclists. Even in cases where an accident results from illegal moves by pedestrians or cyclists, the motorist is almost always found to be at least partly at fault. When the accident involves children or the elderly, the motorist is usually found to be entirely at fault. In almost every case, the police and the courts find that motorists should anticipate unsafe and illegal walking and cycling.

In addition, German and Dutch police are far stricter in ticketing motorists, pedestrians, and cyclists who violate traffic regulations. Thus, walking against the light is not allowed in any German city and can easily result in a ticket and fine. Likewise, cyclists caught riding in the wrong direction, running red lights, making illegal turns, or riding at night without functioning lights can expect at least a warning notice and possibly a ticket and fine.

The most significant contrast with the United States is the much stricter enforcement of traffic regulations for motorists in Germany and The Netherlands. Penalties can be high even for minor violations. Not stopping for pedestrians at crosswalks is considered a serious offense and motorists can get ticketed for noncompliance, even if pedestrians are only waiting at the curb and not actually in the crosswalk.[10] Similarly, red traffic signals are strictly enforced, and some intersections in German and Dutch cities have cameras that automatically photograph cars running red lights and stop signs.[37] Finally, the punishment for traffic violations by motorists is far more severe in The Netherlands and Germany than in the United States.[45]

CONCLUSIONS

The neglect of pedestrian and bicycling safety has made walking and cycling dangerous ways of getting around American cities. Walking and cycling can be made quite safe, however, as clearly shown by the much lower fatality and injury rates in The Netherlands and Germany. There is no good reason why American cities could not adopt many of the same measures to enhance safety. The necessary methods and technology are already available, with decades of successful experience in Europe.

It is important to package safety-enhancing programs in a way that dramatizes their benefits to everyone. The most obvious benefit would be the reduced risk of death and injury from walking and cycling. The safety issue must be brought home to Americans by public campaigns emphasizing the direct impacts on individuals, their families, and their friends. Improved safety also would encourage more people to walk and cycle on a regular basis, providing them with valuable exercise, mobility options, independence, and even fun.

The European countries with the highest levels of walking and cycling have much lower rates of obesity, diabetes, and hypertension than the United States.[25,48] The Netherlands, Denmark, and Sweden, for example, have obesity rates only a third of the American rate, while Germany's rate is only half as high.[48] Moreover, the average healthy life expectancies in those 4 European countries are 2.5 to 4.4 years longer than in the United States,[25] although their per capita health expenditures are only half those of the United States.[49]

Of course, many factors affect differences between Europe and the United States. Nevertheless, the dramatically higher levels of walking and cycling for daily travel certainly contribute to better public health in countries such as The Netherlands, Denmark, Germany, and Sweden. Repeated waves of fad diets, rising memberships in health clubs, exercise equipment in more homes, diet pills, and liposuction have all been total failures in fighting the current obesity epidemic. Why not try integrating walking and cycling into the daily travel routines of Americans? That clearly would be the cheapest, most reliable, and most practical way to ensure adequate levels of physical exercise.

Walking and cycling also help alleviate traffic congestion, save energy, reduce air and noise pollution, conserve land, and produce various other environmental benefits. It is the broad spectrum of benefits from walking and cycling that explains the widespread public support in The Netherlands and Germany for the impressive range of policies they have adopted to make walking and cycling safer, more convenient, and more pleasant.

The same synergistic benefits have the potential for energizing a broad coalition of groups in the United States to advocate better walking and cycling conditions in American cities. Public health experts should be working together with bicyclist and pedestrian advocates, traffic engineers, urban planners, environmentalists, architects and private developers, community leaders, and government officials at all levels. The public health community probably has the most potential to encourage the necessary changes at the grassroots level. Unless individual Americans can be convinced that they will directly benefit from better walking and cycling conditions, politicians are unlikely to support the necessary policies. Self-interest is likely to be the strongest motivation to effect changes in travel behavior. Getting enough physical exercise is quite literally a matter of life or death. Health care professionals must convince their patients that walking and cycling on a regular basis for daily travel will help them live longer and healthier lives.

Of course, the public health community cannot do it alone. Transportation professionals, urban planners, architects, and private developers must provide the improvements in walking and cycling conditions so desperately needed to reduce the dangers of walking and cycling in American cities. Those efforts will require the support of local, state, and federal government officials. Public policymakers at all levels must not only provide the necessary funding for better bicycling and pedestrian facilities but also adopt and implement a range of policies to encourage more compact,

mixed-use development that naturally permits and encourages walking and cycling as a part of daily life.

If for no other reason than their large numbers and extensive network of contacts, public health experts have a crucial role to play in mobilizing political support for the necessary policy changes. At the very least, they should publicize more prominently the disastrous public health consequences of an automobile-dependent transportation system and a land-use pattern that make walking and cycling dangerous, inconvenient, unpleasant, and, in some cases, impossible.

In fact, the public health community has already begun developing programs and partnerships to achieve more walkable and bikable communities that encourage higher levels of physical exercise. The CDC, for example, has developed the Active Community Environments (ACE) program, a multidisciplinary initiative to promote walking and cycling through better urban design, transportation, and land-use policies.[50] The federal CDC program links up with state health departments to encourage similar efforts at the state and local level. For example, the ACE program in the California Department of Human Services funds organizations such as California Walks, the California Bicycle Coalition, the Local Government Commission, and the Rails-to-Trails Conservancy to encourage local community policies that promote walking and cycling.[51] California's ACE also coordinates the state's Safe Routes to School initiative by providing technical assistance and funding community-based projects that promote walking to school.

Complementing such government initiatives, the Robert Wood Johnson Foundation has already spent $84 million financing a family of Active Living programs, all of which are intended to increase physical activity.[52] Active Living by Design, for example, is funding 25 communities throughout the country to promote changes in urban design, architecture, land use, and transportation that encourage more walking and cycling. Active for Life focuses on incorporating increased exercise into the daily life of adults. The foundation's Active Living Network is intended to integrate the public health agenda into a wide range of other professions crucial to improving walking and cycling conditions, thus explicitly fostering the necessary partnership and teamwork.

However admirable these initial efforts are, they remain exceedingly modest compared with the enormity of the problem. Public health organizations should publicize far more widely the worsening obesity epidemic in the United States as the national crisis it is. They need to mount massive media campaigns to encourage and improve the conditions for walking and cycling. Only when the public and politicians become fully aware of the severity of the obesity problem—and the huge potential of walking and cycling to mitigate the problem—will public policies change enough to make a real difference.

Some studies predict that obesity will soon overtake smoking as the most important cause of premature death in the United States.[53–55] It is time for the public health community to undertake as vigorous a campaign to promote more physical exercise and improved diet as the decades-long campaign against smoking. ■

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J. Pucher had primary responsibility for the study design, data collection for Germany and the United States, and writing the text of the article. L. Dijkstra shared in the study design, collected data for The Netherlands, and produced the graphics.

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Endnotes

1. A.H. Mokdad, B.A. Bowman, E.S. Ford, F. Vivicor, J.S. Marks, and J.P. Koplan, "The Continuing Epidemics of Obesity and Diabetes in the United States," *JAMA* 286 (2001): 1195–1200.

2. K. Flegal, M. Carroll, C. Ogden, and C. Johnson, "Prevalence and Trends in Obesity Among Adults, 1999–2000," *JAMA* 288 (2002): 1723–1727.

3. C. Dora, "A Different Route to Health: Implications of Transport Policies," *British Medical Journal* 318 (1999): 1686–1689.

4. J. Koplan and W. Dietz, "Caloric Imbalance and Public Health Policy," *JAMA* 282 (1999): 1579–1581.

5. D. Carnall, "Cycling and Health Promotion," *British Medical Journal* 320 (2000): 888.

6. S.P. Wolff and C.J. Gilham, "Public Health Versus Public Policy? An Appraisal of British Urban Transport Policy," *Public Health* 105 (1991): 217–228.

7. M. Hillman, "Health Promotion: The Potential of Non-Motorized Transport," in *Health at the Crossroads: Transport Policy and Urban Health*, ed. T. Fletcher and A.J. McMichael (London: Wiley and Sons, 1997): 177–186.

8. *Physical Activity and Health: A Report of the Surgeon General* (Atlanta, Ga: Centers for Disease Control and Prevention, 1996); *Healthy People 2010: Understanding and Improving Health*, 2d ed. (Washington, DC: US Department of Health and Human Services, November 2000).

9. J. Pucher and J. Renne, "Socioeconomics of Urban Travel: Evidence From the 2001 NHTS," *Transportation Quarterly* 57 (2003): 49–77; based on data from *2001 National Household Travel Survey* (Washington, DC: US Department of Transportation, Federal Highway Administration, 2003). Article also available at http://nhts.ornl.gov/2001/Documents/Pucher-Renne-TQarticle.pdf. Accessed July 18, 2003. These calculations are for urban areas only, but they include all trip purposes and all means of transportation. The survey description and detailed data are available at: http://nhts.ornl.gov/2001/index.shtml. Accessed December 15, 2002.

10. J. Pucher and L. Dijkstra, "Making Walking and Cycling Safer: Lessons From Europe," *Transportation Quarterly* 54 (2000): 25–50. A version without photos is available as a pdf file at: http://www.vtpi.org/puchertq.pdf. Accessed December 15, 2002.

11. *1995 Nationwide Personal Transportation Survey* (Washington, DC: Federal Highway Administration, 1997); *2001 National Household Travel Survey* (Washington, DC: Federal Highway Administration, 2003).

12. *Traffic Safety Fact Sheets* (Washington, DC: US Department of Transportation, National Highway Traffic Safety Administration, annual). Available at: http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2001/2001pedestrian.pdf and http://www-nrd.nhtsa.dot.gov/pdf/nrd-30/NCSA/TSF2001/2001pedal.pdf. Accessed December 15, 2002.

13. *WISQARS: Web-Based Injury Statistics Query and Reporting System (Online)* (Atlanta, Ga: National Center for Injury Prevention and Control, annual). Available at: http://www.cdc.gov/ncipc/wisqars. Accessed December 15, 2002.

14. W. Broeg and E. Erl, *Einflussgrössen der Personenmobilität* (Berlin: German Ministry of Transport, Building, and Housing, 2002).

15. W. Broeg and E. Erl, *Kenngrössen für Fussgänger- und Fahrradverkehr* (Berlin: German Ministry of Transport, Building, and Housing, 1999).

16. German Institute of Economic Research, *Verkehr in Zahlen* (Berlin: German Ministry of Transport, annual).

17. Central German Statistical Office (Statistisches Bundesamt), Stuttgart, special disaggregate tabulations of population, travel, and accidents done for the authors for western and eastern portions of Germany.

18. Federal Traffic Institute (Bundesanstalt für Strassenwesen), *IRTAD: International Road Traffic Accident Database* (Bergisch-Gladbach, Germany: Federal Traffic Institute, annual). Available at: http://www.bast.de/htdocs/fachthemen/irtad/english/englisch.html. Accessed December 15, 2002.

19. *Personenvervoer over de weg* (Voorburg/Heerlen: Statistics Netherlands, annual). Available at: http://www.cbs.nl. Accessed December 15, 2002.

20. Dutch Ministry of Transport, Public Works, and Water Management, *Nederland-Slachtoffers naar vervoerwijze en aard letsel* (Rotterdam/Heerlen: AVV Transport Research Center, quarterly). Available at: http://www.rws-avv.nl. Accessed December 15, 2002.

21. International Road Traffic and Accident Database, *Underreporting of Road Traffic Accidents Recorded by the Police: An International Comparison* (Bergisch-Gladbach, Germany: Organization for Economic Cooperation and Development, Road Research Transport Program, November 1994).

22. Dutch Institute for Road Safety Research, *Victims, Road Accident Victims: General Developments, Official Statistics and the Real Numbers* (Leidschendam, The Netherlands, 1997). Available at: http://www.swov.nl/en/kennisbank/index.htm. Accessed December 15, 2002.

23. Pucher and Renne, "Socioeconomics of Urban Travel," Table 1. Available at http://nhts.ornl.gov/2001/Documents/Pucher-Renne-TQarticle.pdf. Accessed August 10, 2003.

24. We used the 1995 Nationwide Personal Transportation Survey (NPTS) modal split figures here for the United States even though 2001 National Household Travel Survey (NHTS) statistics are available. Comparable 2000 or 2001 travel survey data are not yet available for the other countries shown in Figure 1. Moreover, the 2001 walk share reported by the NHTS is not even comparable with the earlier NPTS surveys of American walking levels, because 2001 survey methodology was drastically changed to capture more walk trips, definitely exaggerating any real increase in walking between 1996 and 2001.

25. Healthy life expectancy refers to the expected years of life without a major disability or illness that significantly impairs the quality of life. C. Dathers, *Estimates of Healthy Life Expectancy for 191 Countries in the Year 2000: Methods and Results* (Geneva, Switzerland: World Health Organization, October 2001), Annex Table A; Global Programme on Evidence for Health Policy Discussions Discussion Paper No. 38.

26. P. Newman and J. Kenworthy, *Sustainability and Cities: Overcoming Automobile Dependence* (Washington, DC: Island Press, 1999), 68–125.

27. R. Ewing and R. Cervero, "Travel and the Built Environment," *Transportation Research Record* 1780 (2001): 87–114.

28. The 2001 NHTS reports a higher percentage of walk trips in American cities (8.6% in 2001 compared with 5.4% in 1995), but the increase is solely due to a very important change in survey methodology, which introduced multiple prompts by survey interviewers to capture all possible walk trips. Thus, the 2001 walk share figure for the United States is not comparable with earlier NPTS surveys in 1977, 1983, 1990, and 1995. For full details of both the earlier NPTS surveys and the 2001 NHTS survey, as well as detailed analysis of socioeconomic variations and time trends, see Pucher and Renne, "Socioeconomics of Urban Travel." For that reason, and also because we have only 1995 walk share data for most other European countries, we have used the 1995 modal split shares for international comparisons in this article.

29. Transportation Research Board, *Making Transit Work: Insight from Western Europe, Canada, and the United States* (Washington, DC: National Academy Press, 2001).

30. The authors calculated fatality rates based on official mode-by-mode fatality and travel statistics of the US Department of Transportation (National Highway Traffic Safety Administration and Federal Highway Administration). The total numbers of car occupant, cyclist, and pedestrian fatalities were derived from National Highway Traffic Safety Administration, *Traffic Safety Facts 2001* (Washington, DC: US Department of Transportation, 2003). The total number of passenger kilometers of travel by private motor vehicle, bicycle, and foot were calculated for the authors by Mary Ann Keyes of the Federal Highway Administration using unpublished data from the 2001 National Household Travel Survey.

31. N. Templin, "The Bicycle Loses Ground as a Symbol of Childhood Liberty," *Wall Street Journal* (September 10, 1996), A1.

32. J. Pucher, C. Komanoff, and P. Schimek, "Bicycling Renaissance in North America? Recent Trends and Alternative Policies to Promote Bicycling," *Transportation Research A* 33 1999: 625–654. Available at: http://policy.rutgers.edu/papers, accessed December 15, 2002.

33. P. Van Vliet and G. Schermers, *Sustainable Safety: A New Approach for Road Safety in the Netherlands* (Rotterdam: Ministry of Transport, Public Works and Water Management; Traffic Research Centre, 2000). Available at:http://www.rws-avv.nl. Accessed December 15, 2002.

34. *National Traffic and Transport Plan* (The Hague: Ministry of Transport, Public Works and Water Management, 2000). Available at: http://www.minvenw.nl. Accessed December 15, 2002.

35. *Nationaler Radverkehrsplan 2002–2012, FahrRad! Massnahmen zür Förderung des Radverkehrs in Deutschland.* Berlin: Bundesministerium für Verkehr, Bau- und Wohnungswesen, April 2002). Available at: http://www.bmvbw.de/Fahrradverkehr-.423.htm. Accessed December 15, 2002.

36. V. Vuchic, *Transportation for Livable Cities* (New Brunswick, NJ: Center for Urban Policy Research, 1999).

37. C. Zeeger, *FHWA Study Tour for Pedestrian and Bicyclist Safety in England, Germany, and The Netherlands* (Washington, DC: US Department of Transportation, Federal Highway Administration, 1994).

38. R. Cervero, *Transit Metropolis: A Global Inquiry* (Washington, DC: Island Press, 1998).

39. R. Tolley, ed, *Greening of Urban Transport* (Chichester, England: Wiley Press, 1997).

40. *Sign up for the Bike—Design Manual for a Cycle-Friendly Infrastructure* (Ede, The Netherlands: Information and Technology Centre for Transport and Infrastructure, 1998).

41. *Traffic Calming in the Netherlands* (Ede, The Netherlands: Information and Technology Centre for Transport and Infrastructure, 1998).

42. *Mean Streets: Pedestrian Safety and Reform of the Nation's Transportation Law* (Washington, DC: Surface Transportation Policy Project, 1997), Table 4, p. 4.

43. J. Kraay and A. Dijkstra, *Safety Aspects of Urban Infrastructure* (Leidschendam, The Netherlands: Institute for Road Safety Research, 1989).

44. C. Hass-Klau, *Civilized Streets: A Guide to Traffic Calming, Environment, and Transport Planning* (Brighton, England: Brighton Press, 1992).

45. B. Preston, "Cost-Effective Ways to Make Walking Safer for Children and Adolescents," *Injury Prevention* 1 (1995): 187–190.

46. German Traffic Safety Council, *Kind und Verkehr: Nationales Programm des Deutschen Verkehrssicherheitsrat zur Verkehrserziehung in Deutschland* (Berlin: Deutscher Verkehrssicherheitsrat, 2001). Available at: http://dvr.de/asp/dms.asp?url=programme/kind/inhalt.htm. Accessed December 15, 2002.

47. Kultusministerium, "Beschluss der Kultusministserkonferenz vom 17.6.1994," *Zeitschrift für Verkehrserziehung* 45 (1995): 4–6.

48. World Health Organization, *Obesity in Europe: The Case for Action* (London: International Obesity Taskforce of the World Health Organization, September 2002). Available at: http://www.iotf.org/media/globalprev.htm. Accessed December 15, 2002.

49. *Total Expenditures on Health per Capita, 1960–2000, in US Dollars, Purchasing Power Parity* (Washington, DC: Organization for Economic Cooperation and Development, 2002). Available at: http://www.oecd.org/xls/M00031000/M00031378.xls. Accessed December 15, 2002.

50. Centers for Disease Prevention and Control, *Active Community Environments* (Atlanta, Ga: National Center for Chronic Disease Prevention and Health Promotion, 2003). Available at: http://www.cdc.gov/nccdphp/dnpa/aces.htm. Accessed December 15, 2002.

51. *Physical Activity and Health Initiative* (Sacramento: Department of Health and Human Services, 2002). Available at: http://www.dhs.ca.gov/cdic/cdcb/epidemiology/Physical_Activity/index.htm. Accessed December 15, 2002.

52. *Active Living Resource Center* (Princeton, NJ: Robert Wood Johnson Foundation, 2003). Available at: http://www.rwjf.org/programs/physicalActivity.jsp. Accessed December 15, 2002.

53. J.M. McGinnis and W.H. Foege, "Actual Causes of Death in the United States," *JAMA* 270 (1993): 2207–2212.

54. A. Peeters, J.J. Barendregt, F. Willekens, J.P. Mackenbach, A. Al Mamum, and L. Bonneux, "Obesity in Adulthood and Its Consequences for Life Expectancy: A Life-Table Analysis," *Annals of Internal Medicine* 138 (2003): 24–32.

55. R. Sturm, "The Effects of Obesity, Smoking and Drinking on Medical Problems and Costs: Obesity Outranks Both Smoking and Drinking in Its Deleterious Effects on Health and Health Costs," *Health Affairs* 21 (2002): 245–253.

Jemez Pueblo: Built and Social-Cultural Environments and Health Within a Rural American Indian Community in the Southwest

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Much has been written about built and social-economic environments and their effects on urban health.[1–7] A growing literature also proposes that community capacity and social capital[8–15] play a role in reducing health risks. Another promising area of study is how cultural identity informs symbolic meanings of place and land, which affect health determinants.[16,17] Rural populations, although they have received less study, present an opportunity for research because their social and cultural identities are largely based on land and place. In this brief, we present preliminary results of one such study in a tribal community, raising questions about the intersections of built and sociocultural environments and health.

The Pueblo of Jemez is situated in rural New Mexico. More than 90% of its nearly 3400 members speak the Towa language. The unemployment rate is 27%, and 30% of all heads of households are not high school graduates. Most of those who are employed work in tribal services or in nearby cities.

METHODS

In 1999, the University of New Mexico Masters of Public Health Program received a 3-year grant from the Centers for Disease Control and Prevention as part of a national study to identify cultural meanings of community capacity in ethnic minority communities. This study used participatory research[18] to uncover sociocultural and environmental factors that indicate capacity for improving health.

With approvals from tribal leadership, the University of New Mexico team developed a tribal advisory committee, which co-developed the instruments. Informants were identified by sectors: elders, youth, spiritual leaders, political leaders, health, environment, and education.[19] Thirty-seven people participated in 5 focus groups; 30 were interviewed. We used a modified grounded theory approach[19] and worked with the advisory committee to analyze qualitative data. Although the built environment was not the research focus, we found that issues of housing, land use, and cultural practice were interconnected with community health.

RESULTS

Several unique contextual characteristics underlie this tribal environment. First, the tribal government makes all decisions about development, so no contests exist between public, private, and civil sectors. Second, decisions about the built environment are dominated by traditional connections to the natural environment and culture. Third, although societal changes—such as the breakup of families and media influence—have affected the pueblo, they are countered by uniformly shared values of cultural practice, language use, and sense of community. "We're a community . . . everyone chips in . . . before you know it, you have a house full of people willing to help." "Our culture makes people who they are, a sense of belonging. . . . Traditions, language make it unique." Fourth, the pueblo's access to resources has been historically limited, but increased tribal sovereignty has enabled Jemez to take control of its health care and to pursue charter schools.

Table 1 presents 3 built environment issues raised at Jemez: housing, Red Rocks development, and program development. For tribal leadership, these issues raise competing pressures for cultural preservation, economic development, family needs, community priorities, and, ultimately, health.

Housing

Although everyone agrees that the pueblo needs more housing, the issues are extended- or single-family dwellings, tribal government control over family lands, and placement of new housing.

Although the consensus is that extended family living is culturally appropriate, there are health and privacy concerns. "A lot of adults and families living in one house . . . that causes a lot of stress." Overcrowding prompts families to want to build on family farmlands, which is discouraged by the tribal council because of water rights litigation. "If we can't build homes on our farmland, where else are we going to build?"

Some tribal members want new housing at the edge of the village: "People with tribal enterprises need space." Others fear loss of co-

TABLE 1—Competing Pressures in Built Environment

Built Environment	Competing Pressures
Housing	
Inadequate supply	New housing vs traditional land use
Land use decisions	Plaza village vs distant suburbs
Family changes	Intergenerational vs nuclear vs single-mother families
Red Rocks development	
Road bypass	Economic development vs cultural preservation
Convenience store	Healthy commerce vs fast food
Museum	Government controlled vs family tourism
Program development	
New youth and senior centers	Service recipient vs community participant
Health facility	Tribal vs outside control

hesiveness with building homes far from the village center. "I just hope we don't get into developments like you see in the cities, like apartments." "New homes separate the pueblo life."

Red Rocks Development

Outside the village is the beautiful Red Rocks area, which hosts a tourist museum, convenience store, and food booths. A planned road bypass around the village to Red Rocks is a strategy to maintain tribal community: "It's nice we don't get the intruders. . . . That's what pulls our people together because we try to keep our traditions alive." "I totally support the bypass, for people to survive for the next 1000 years." However, this planned development creates tension among families who sell arts and crafts from their homes.

Economic development with health planning also remains a challenge. The convenience store employs tribal members and brings in revenue, but it is too far from the pueblo to walk, and it offers processed, convenience foods. "It would be nice if we could buy fresh vegetables, fruits. . . . It's more like fast food, fat foods."

Program and Facilities Expansion

Jemez is not a gaming tribe; it relies on federal resources for much-needed programs. A significant contribution to the built environment has been new health, senior, and youth facilities. Although proud of the infrastructure growth, program staff are concerned about potential decline in community participation as more people relate to tribal government as service recipients. On the other hand, tribal members appreciate participating in health programs linked to their culture: "You always greet people on the [health] walks . . . people like that." "We have more prevention programs, [which] continue in our Indian way . . . elders teach our young."

DISCUSSION

Preliminary findings indicate that built, sociocultural, and natural environments are interconnected. By assessing health-related community capacities, this study raised questions about how built environments can maintain cultural integrity and still foster health. For Jemez, cultural maintenance may take priority over economic and infrastructure needs, which paradoxically both enhances and threatens health opportunities. The more explicit these paradoxes are in tribal decisionmaking, the more capacity the tribe may have to weigh contributions of culture, economics, and environment on people's health. These preliminary results point to the need to investigate material, sociocultural, and symbolic meanings of place as we continue to study built environments and health. ■

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Contributors

N. Wallerstein and B.M. Duran wrote the brief. All contributors assisted with the study design, data collection, and analysis.

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Human Participant Protection

The University of New Mexico Health Science Center human research review committee approved this study. The Jemez Pueblo health board and tribal council approved the study and this publication.

References

1. Diez Roux AV. Investigating neighborhood and area effects on health. *Am J Public Health.* 2001;91:1783–1789.

2. Yen I, Syme L. The social environment and health: a discussion of the epidemiology literature. *Annu Rev Public Health.* 1999;20:287–308.

3. Massey DS, Denton NA. Hypersegregation in U.S. metropolitan areas: black and Hispanic segregation along five dimensions. *Demography.* 1989;26:373–391.

4. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health.* 2002;92:758–768.

5. Wilson WJ. *The Truly Disadvantaged: The Inner City, the Underclass, and Public Policy.* Chicago, Ill: University of Chicago Press; 1987:xi, 254.

6. Jackson RJ, Kochtitzky C, Sprawl Watch Clearinghouse. *Creating a Healthy Environment: The Impact of the Built Environment on Public Health.* Washington, DC: Sprawl Watch Clearinghouse; 2001:19. Sprawl Watch Clearinghouse Monograph Series.

7. Cummins SK, Jackson RJ. The built environment and children's health. *Pediatr Clin North Am.* 2001;48:1241–1252.

8. Putnam RD. Bowling alone: America's declining social capital. *J Democracy.* 1993;6:65–78.

9. Lochner K, Kawachi I, Kennedy BP. Social capital: a guide to its measurement. *Health Place.* 1999;5:259–270.

10. Lindstrom M, Merlo J, Ostergren PO. Individual and neighbourhood determinants of social participation and social capital: a multilevel analysis of the city of Malmo, Sweden. *Soc Sci Med.* 2002;54:1779–1791.

11. Baum FE, Bush RA, Modra CC, et al. Epidemiology of participation: an Australian community study. *J Epidemiol Community Health.* 2000;54:414–423.

12. Lindstrom M, Hanson BS, Ostergren PO. Socioeconomic differences in leisure-time physical activity: the role of social participation and social capital in shaping health related behaviour. *Soc Sci Med.* 2001;52:441–451.

13. Sampson RJ, Raudenbush SW, Earls F. Neighborhoods and violent crime: a multilevel study of collective efficacy. *Science.* 1997;277:918–924.

14. Parker EA, Lichtenstein RL, Schulz AJ, et al. Disentangling measures of individual perceptions of community social dynamics: results of a community survey. *Health Educ Behav.* 2001;28:462–486.

15. Goodman RM, Speers MA, McLeroy K, et al. Identifying and defining the dimensions of community capacity to provide a basis for measurement. *Health Educ Behav.* 1998;25:258–278.

16. Jackson P, Penrose J, Association of American Geographers. *Meeting: Constructions of Race, Place, and Nation.* Minneapolis: University of Minnesota Press; 1994:viii, 216.

17. Gesler WM, Kearns RA. *Culture Place Health: Critical Geographies.* London, England: Routledge; 2002:xi, 182.

18. Minkler M, Wallerstein N. *Community Based Participatory Research for Health.* San Francisco, Calif: Jossey-Bass; 2003:xxxiii, 490.

19. Glaser BG, Strauss AL. *The Discovery of Grounded Theory; Strategies for Qualitative Research.* Chicago, Ill: Aldine Publishing Co; 1967:x, 271.

Places to Walk: Convenience and Regular Physical Activity

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Regular physical activity fosters good physical and mental health.[1] Described as "today's best buy in public health,"[2] one needs to accumulate only 30 minutes per day, 5 days per week, of moderately intense physical activity, such as brisk walking.[3] For almost everyone, walking is a familiar activity performed in the conduct of normal daily activities. Nevertheless, only 25% to 30% of Americans report doing activities that meet current recommendations for physical activity, and 30% to 40% report no participation in physical activities away from their work.[4,5] These data have not changed over at least the past decade.[5]

The availability[6–8] and awareness[9] of places conducive to physical activity are associated with higher levels of physical activity. To guide our efforts to promote regular physical activity, we used the Georgia Behavioral Risk Factor Surveillance System to determine (1) whether adult Georgians were aware of safe and convenient places for walking, (2) what places they most commonly envisioned, and (3) whether the proximity of those places was associated with self-reported physical activity behaviors.

METHODS

Data were collected via the Georgia Behavioral Risk Factor Surveillance System, a random-digit-dialed telephone survey of health-related behaviors of adults aged 18 years and older.[10] The 2001 questionnaire (available at http://www.cdc.gov/brfss/pdf-ques/2001brfs.pdf) asked about the frequency and duration of both moderate and vigorous physical activity. Respondents were categorized as meeting current recommendations for activity or not (moderate activity for at least 30 minutes per day, 5 days per week, or vigorous activity for at least 20 minutes per day, 3 days per week).

In Georgia, we added questions about safe and convenient places to walk. Respondents were informed that they would be asked "about places where people can walk for exercise or recreation, such as trails, parks, sidewalks, and treadmills" and that the survey was concerned with "their convenience and safety for you, whether or not you actually use them." Respondents were then asked, "Is there a place you could go where you would feel safe walking for exercise or recreation?" If they responded, "yes," they were asked, "What is the most convenient place? Is it . . . ?," and they were read the places listed in Table 1. If the place was their neighborhood or a home treadmill, we assumed that the respondent could walk to the place in less than 10 minutes. All others were asked, "How many minutes would it take to get there from your home?" and "How would you get there?" Three categories of convenience were created based on time and mode of travel to the place: (1) less than 10 minutes walking, (2) less than 10 minutes not walking, and (3) 10 minutes or greater regardless of mode.

In 2001, 4532 persons responded to the survey. Responses were weighted to provide population-based estimates for Georgia. Data were analyzed with SUDAAN software to account for the complex survey design.[11] Tests for linear trend across categories of convenience were done according to the method of Fisher and Yates.[12]

TABLE 1—Walking Places, by Time and Method to Reach Place: Georgia Behavioral Risk Factor Surveillance System, 2001

		Time and Method to Reach Place		
Walking Places	N	<10 Min Walk % (95% CI)	<10 Min Do Not Walk % (95% CI)	≥10 Min All Methods % (95% CI)
No place to walk	382	NA	NA	NA
Some place to walk	3949	47.1 (45.1, 49.1)	21.1 (19.5, 22.8)	31.8 (45.1, 49.1)
Not home based	2472	16.2 (14.2, 18.2)	33.5 (31.0, 36.0)	50.3 (47.7, 52.8)
Public park	1017	13.3 (10.5, 16.0)	35.4 (31.5, 39.2)	51.4 (47.4, 55.5)
School track	416	10.7 (7.2, 14.2)	43.0 (37.2, 48.9)	46.1 (40.3, 52.0)
Gym or fitness center	279	11.1 (5.5, 16.6)	29.6 (22.2, 37.0)	59.4 (51.5, 67.3)
Walking or jogging trail	263	28.5 (21.5, 35.6)	31.7 (24.9, 38.5)	39.7 (32.7, 46.8)
Shopping mall	120	[a]	21.5 (12.2, 30.9)	72.0 (60.8, 83.1)
Other place[b]	377	30.6 (23.1, 38.1)	25.0 (18.6, 31.4)	44.2 (36.3, 52.2)
Home based	1477	100.0[c]	0[c]	0[c]
Neighborhood streets or roads	680	100.0[c]	0[c]	0[c]
Neighborhood sidewalk	638	100.0[c]	0[c]	0[c]
Treadmill at home	159	100.0[c]	0[c]	0[c]

Note. % = percent weighted to Georgia population; CI = confidence interval; NA = not applicable, no walking place reported.
[a]Not calculated, <10 respondents in cell.
[b]No specific information was obtained about other place.
[c]Assumed to be 100% or 0%.

RESULTS

An estimated 91.8% (95% confidence interval [CI]=90.8%, 92.8%) of Georgians had a place where they would feel safe walking for exercise or recreation. The most commonly reported place was neighborhood streets or sidewalks (32.0%; 95% CI=30.2%, 33.8%), followed by public parks (26.8%; 95% CI=25.0%, 28.6%), school track (10.2%; 95% CI=9.1%, 11.4%), gym or fitness center (7.8%; 95% CI=6.6%, 9.0%), walking or jogging trail (6.6%; 95% CI=5.7%, 7.6%), treadmill at home (4.1%;

TABLE 2—Percent Meeting Physical Activity Recommendations, by Walking Place and Time and Method to Reach Place: Georgia Behavioral Risk Factor Surveillance System, 2001

	Time and Method to Reach Place				
Walking Places	All Times All Methods % (95% CI)	<10 Min Walk % (95% CI)	<10 Min Do Not Walk % (95% CI)	≥10 Min All Methods % (95% CI)	*P* for Trend
No place to walk	27.4 (21.2, 33.7)	NA	NA	NA	
Some place to walk	41.5 (39.4, 43.6)	43.0 (40.1, 46.0)	42.5 (37.9, 47.0)	38.1 (34.3, 41.9)	.04
Not home based	41.6 (38.9, 44.3)	49.4 (42.5, 56.3)	42.5 (37.9, 47.0)	38.1 (34.3, 41.9)	.005
Public park	39.6 (35.6, 43.6)	51.8 (40.3, 63.4)	39.2 (32.6. 45.7)	36.7 (31.1, 42.3)	.02
School track	42.7 (36.5, 48.8)	48.4 (30.2, 66.5)	47.8 (38.3, 57.3)	36.8 (28.1, 45.6)	.26
Gym or fitness center	45.3 (37.2, 53.4)	52.7 (25.0, 80.5)	54.2 (38.9, 69.5)	37.4 (28.3, 46.4)	.30
Walking or jogging trail	45.1 (37.5, 52.7)	51.6 (35.9, 67.2)	45.0 (31.4, 58.5)	40.2 (29.1, 51.3)	.24
Shopping mall	32.1 (21.0, 43.1)	[a]	48.4 (22.4, 74.5)	28.5 (16.8, 40.3)	
Other place[b]	43.4 (35.6, 51.1)	46.1 (33.0, 59.1)	27.5 (14.7, 40.4)	49.4 (36.0, 62.7)	.73
Home based	41.3 (38.1, 44.6)	41.3 (38.1, 44.6)	NA	NA	
Neighborhood streets or roads	41.8 (37.0, 46.6)	41.8 (37.0, 46.6)	NA	NA	
Neighborhood sidewalk	41.3 (36.3, 46.3)	41.3 (36.3, 46.3)	NA	NA	
Treadmill at home	39.7 (29.8, 49.6)	39.7 (29.8, 49.6)	NA	NA	

Note. % = percentage weighted to Georgia population; CI = confidence interval; NA = not applicable, no respondents in cell.
[a]Not calculated, <10 respondents in cell.
[b]No specific information was obtained about other place.

95% CI=3.3%, 4.9%), or shopping mall (2.9%; 95% CI=2.2%, 3.5%). Omitting those whose place was their neighborhood or treadmill at home, 49.7% (95% CI=47.2%, 52.3%) reported that they could reach the place in less than 10 minutes; 75.9% (95% CI=73.6%, 78.1%) reported that they would drive there, and 22.4% (95% CI=20.2%, 24.6%) reported that they would walk.

Including persons whose place to walk was their neighborhood or home treadmill, 47.1% (95% CI=45.1%, 49.1%) of persons could walk to their place in less than 10 minutes (Table 1). However, fewer than 15% of the persons whose place was a public park, school track, gym or fitness center, or shopping mall could walk to their place in less than 10 minutes.

Persons reporting a place to walk were significantly more likely to meet current recommendations for regular physical activity (41.5%; 95% CI=39.4%, 43.6%) than were those reporting no place to walk (27.4%; 95% CI=21.2%, 33.7%) (Table 2). There was a direct relation between the convenience of the walking place and the proportion of respondents meeting current activity recommendations. The trend across categories of convenience was significant for all places combined, places not home based, and public parks (Table 2). The same direct pattern was seen for other specified places, but the trend was not significant.

DISCUSSION

Most adult Georgians can envision a safe and convenient place for walking. In addition, a direct relation exists between the convenience of the place and meeting activity recommendations. Those able to walk to the place in less than 10 minutes are most likely to be active. These data support previous reports[6–8] indicating the value of convenient places for activity. Our findings provide specificity to that knowledge by confirming the association between awareness of places and physical activity practices,[9] noting that neighborhood streets and sidewalks and public parks are the most commonly reported safe and convenient places for walking,[8] noting the association between self-reported convenience (time and method of getting to place) and physical activity, and suggesting that the association holds for most places included in the survey.

Our conclusions might be strengthened if we had evidence that the respondents actually used the place they envisioned for walking. However, the questions we asked were simple, have construct validity, and, based on their association with self-reported behaviors, have predictive validity. It is programmatically helpful to know that most Georgians can envision and identify a safe and convenient place to walk.

The data suggest that proximity is an important factor in the identification of a safe and convenient place to walk. The most commonly mentioned place was the respondent's neighborhood. Public parks were the next most commonly mentioned place. Efforts to design new and to retrofit old neighborhoods with sidewalks and streets that make them easily walkable and the development of nearby park space would appeal to residents and be beneficial from a public health perspective. ■

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Contributors

K.E. Powell and L.M. Martin recognized the opportunity to obtain helpful programmatic information and designed the questions. L.M. Martin and P.P. Chowdhury analyzed the data. K.E. Powell drafted the article that was revised by all 3 authors.

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References

1. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, Ga: Centers for Disease Control and Prevention; 1996.

2. Morris JN. Exercise in the prevention of coronary heart disease: today's best buy in public health. *Med Sci Sports Exerc.* 1994;26:807–814.

3. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* 1995;273:402–407.

4. Schoenborn CA, Barnes PM. Leisure-time physical activity among adults: United States, 1997–1998. *Adv Data Vital Health Stat.* April 7, 2002;325.

5. Centers for Disease Control and Prevention. Physical activity trends—United States, 1990–1998. *MMWR Morb Mortal Wkly Rep.* 2001;50(9):166–169.

6. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity, a systematic review. *Am J Prev Med.* 2002;22(4S):73–107.

7. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med.* 2002;22:188–199.

8. Giles-Corti B, Donovan RJ. The relative influence of individual, social, and physical environment determinants of physical activity. *Soc Sci Med.* 2002;54:1793–1812.

9. Leslie E, Owen N, Salmon J, et al. Insufficiently active Australian college students: perceived personal, social, and environmental influences. *Prev Med.* 1999;28:20–27.

10. Frazier EL, Franks AL, Sanderson LM. Behavioral risk factor surveillance data. In: *Using Chronic Disease Data: A Handbook for Public Health Practitioners.* Atlanta, Ga: Centers for Disease Control and Prevention; 1992:1–17.

11. *SUDAAN User's Manual, Release 8.0.* Research Triangle Park, NC: Research Triangle Institute; 2001.

12. Fisher RA, Yates F. *Statistical Tables for Biological, Agricultural and Medical Research.* 5th ed. Edinburgh, United Kingdom: Oliver & Boyd; 1938.

Reestablishing Public Health and Land Use Planning to Protect Public Water Supplies

Michael Greenberg, PhD, Henry Mayer, PhD, K. Tyler Miller, Robert Hordon, PhD, and Daniel Knee, MCRP

Objectives. This study measured the extent to which land use, design, and engineering practices could reduce contamination of major public water supplies.

Methods. Key parcels of land were identified in New Jersey, and the potential uncontrolled loading of contaminants was estimated with the US Environmental Protection Agency's Long-Term Hydrologic Impact Assessment model for a variety of land use, design, and engineering scenarios.

Results. High-density per-acre development and engineering controls, along with housing and light commercial activity near main railroads, would substantially reduce runoff.

Conclusions. In New Jersey, government and purveyor action is being taken as a result of, and in support of, these findings. (*Am J Public Health.* 2003;93:1522–1526)

Since the beginning of the industrial revolution, inadequate treatment of human, animal, and industrial wastes has challenged those charged with providing potable water.[1–3] In 1993, more than 100 people in Milwaukee died from *Cryptosporidium,* which underscored the reality that our treatment technologies for water supplies are not foolproof.[3] Yet, leaking landfills, industrial lagoons, feedlots, and terrorists are perceived as greater threats to public health than runoff is.

Building on green lands leads to paving those lands. As a result, rain that would otherwise fall into streams and recharge an aquifer are diverted. The impact of diversion can be seen when the areas downstream become flooded after heavy storms. Water quality is affected by uncontrolled development that leads to runoff from cars, houses, shopping malls, gasoline stations, and the other accoutrements of urban development.[4] Water supplies can be damaged to the point of abandonment by residual debris, oil and grease, animal manure, tire residue, heavy metals, deicing compounds, and pesticides that are washed into watercourses during precipitation events.

Uncontrolled development has already threatened potable water supplies across the United States. The most prominent examples are New York City's 1900-square-mile Croton and Catskill watersheds. Research has found that the major reservoirs, once characterized as producing the best drinking water in the United States, are now threatened by the sprawl-related runoff of street salts, nutrients, and hazardous contaminants.[5]

A proactive policy option is to turn sensitive watershed land into a green buffer by purchasing it or by permitting the transfer of development rights to other less sensitive parcels. Building engineered structures that control runoff is another proactive policy option. We used an important public, potable, surface water supply in New Jersey to illustrate the need to proactively make land use, design, and engineering decisions in support of public health. Specifically, the research answered two questions: (1) What configurations of residential and light commercial land uses pose the most serious threat to water supplies? (2) What land use, design, and engineering options can be used to prevent degradation of water supplies?

METHODS

Study Area

The quality of drinking water is a major issue in New Jersey, as it is throughout the United States. For example, a 2000 poll of 800 New Jersey residents found that 40% believed that the quality of tap water coming into their homes was "only fair" or "poor." It is therefore not surprising that only 26% of New Jersey's residents reported that they drink tap water, compared with 53% of US residents.[6]

Within New Jersey, we focused on Hunterdon and Union Counties to illustrate the remarkably different conditions that call for thoughtful application of design, planning, and environmental health principles to support public health. Hunterdon County contains two major water supply reservoirs: Spruce Run and Round Valley. The Elizabethtown Water Company serves approximately 500 000 people with water from these reservoirs and the upstream areas that feed into them. Most of the shoreline of Spruce Run Reservoir is owned by the state, and thus forms a useful buffer strip. Buffer zones around reservoirs provide a good measure of protection for drinking water. However, most contamination is likely to come from streams and other tributaries feeding into the reservoir, and the lands adjacent to them are mostly privately owned.[7]

It is inevitable that developers will recognize the beauty of the area surrounding the Spruce Run Reservoir and its upstream areas and that they will propose building high-density condominiums, townhouses, or single-family houses along many of these streams. Unfortunately, zoning ordinances that should prevent such development often give way to money and political pressure.[8] In the event of residential development in this area, a local sewage treatment facility doubtless will be required to protect the reservoir and the other local wells from biological contaminants. But even under the best of conditions, it will be difficult to protect the reservoir from the runoff of gasoline, street salts, fertilizers, solvents, urban street wastes, pesticides, and other products of suburban development.

Hunterdon County's population was 70 000 in 1970 and rose to 125 000 in 2001, an increase of 74%, and another 20 000 people and 11 000 jobs are expected by 2010.[9] Hunterdon is one of the most affluent counties in the United States and is a model of the kind of area that attracts people

looking for an idealized rural setting in which to live and work.[9–10]

Union County is about 20 miles away from Hunterdon County and is connected via an interstate highway, but it is a very different environment. The population of Union County in 1970 was 543 000 and the population in 2000 was 506 000, a decrease of about 7%. With a population density of 4800 per square mile, compared with 260 in Hunterdon County, Union County is the very type of the postindustrial urban area that has lost most of its jobs, lost some of its population, became a home for recent immigrants, and was left with a legacy of contaminated sites, or brownfields.[10]

Union County is important in this case study, because it has the potential to host so-called "transit villages"—transit-oriented developments that have high-density housing and commercial settlements in close proximity to train stations for people who prefer to travel by train rather than automobile.[11] Auto-dependent sprawl could be reduced in such a setting.

Estimating Pollutant Loadings

We assessed uncontrolled nonpoint source pollution loads associated with different development densities to evaluate the impact of land use and engineering controls. This assessment required use of soil, geology, land use, and other local data sets.[12,13] We used the Long-Term Hydrologic Impact Assessment (LTHIA) model, which is highly recommended by the US Environmental Protection Agency (EPA) and is accessible via the Internet. The LTHIA model, which was developed in 1994 at Purdue University, has been improved over the years, most notably in 1998 (when nonpoint source pollution was added) and in 1999 (when it became accessible via the Internet).[14] The user provides input data on land use and hydrologic soil type for existing and planned/future conditions; LTHIA then combines this information with local precipitation data to calculate long-term average annual surface runoff.

Uncontrolled pollutant loadings are estimated in pounds per year (except for bacteria, which are estimated millions per 100 ml) for 14 water-quality variables: total nitrogen, total phosphate, suspended solids, lead, copper, zinc, cadmium, chromium, nickel, biochemical oxygen demand (BOD), chemical oxygen demand (COD), oil/grease, fecal coliform, and fecal strep. All of these substances are listed in the EPA's list of drinking-water contaminants (BOD and COD are caused by excess organic matter), and some are clearly hazardous to humans when consumed in fluids.[15] The model's land use categories include residential (various densities), commercial, industrial, parking, open space, water/wetlands, grass/pasture, agricultural, and forest. We compared the impact of current land uses with the results of 2 alternative residential development scenarios: single-family homes on half-acre lots or a density of 2 housing units per acre, and a more dense condominium development of 8 housing units per acre. Other simulations were run, but on the basis of our experience in New Jersey, 2 and 8 represented the range of densities that seemed suitable for this study area.

TABLE 1—Area of Residential and Commercial Land Use in Acres for 2 Residential Development Scenarios: Hunterdon County, NJ

Land Use Categories	Current Baseline	With 8 Housing Units per Acre	With 2 Housing Units per Acre
Forest	1755	865	368
Agricultural	1022	503	214
Grass/pasture	328	162	69
Residential	...	1000	1879
Commercial	...	575	575
Total	3105	3105	3105

Notably, our analysis did not include pesticides, although pesticides represent a threat to public health and ecological systems. We omitted pesticides because the study area has agricultural, grass/pasture, and other land uses that historically have been heavily treated with pesticides (Table 1). To make credible estimates of the impact of urban development on pesticides, we would need to know current pesticide use in the area and the likely pesticide use by residents of the new developments. Neither of these important facts was obtainable; indeed, the pesticide question is always difficult to answer whether the proposed development area is an active farm, pasture, or a forest. Urban development might increase or decrease pesticide runoff.

Locating Sensitive Growth Areas

The Hunterdon County Planning Board provided us with existing land uses and zoning for the Spruce Run watershed area in a geographic information system (GIS) parcel-based format. We focused on the land within a quarter of a mile of the reservoir and its streams, because contamination of this land would have the greatest adverse impact on water quality. We then removed various lands from potential development, including a flood-zone buffer of 300 feet on each side of these waterways, state- or county-owned parks and open space, land located on steep slopes (greater than 15% grade), wetlands and other environmentally or culturally sensitive lands (as defined by the New Jersey Department of Environmental Protection), and lands already developed. Out of the total 25 035 acres (39.1 square miles) of land within the Spruce Run watershed area, we narrowed our focus to 3105 acres (4.9 square miles, or 12.4% of the watershed area) as our primary study area in Hunterdon County. These lands are currently categorized as forest, agricultural, and grass/pasture.

Our development scenarios are based on the assumption that 20 000 people will move into Hunterdon County over the next decade, with an average family size of 2.5 persons per dwelling unit. This population influx will require 8000 new residential units. We restricted commercial and retail development to areas already zoned for that purpose and to new areas that will naturally develop along major highways. A total of 1226 acres are assigned to these uses, including land that will not be covered by the footprints of buildings and associated parking areas and thus will be left in its current condition. We used various housing densities for residential land and calculated what proportion of the projected population increase could relocate on the 1879 remaining acres in this vulnerable area. We found insufficient land in the study area to house 20 000 people assuming that low-density single-family homes will be constructed. Only 3758 homes, at the rate of 2 units per acre, could

TABLE 2—Total Uncontrolled Nonpoint Source Pollution Loadings: Hunterdon County, NJ

	Baseline Pollution Loading	Change With 8 Housing Units per Acre	Change With 2 Housing Units per Acre
Contaminant, lb/y			
Total nitrogen	22 320	4 457	745
Total phosphate	5 447	1 771	1 048
Suspended solids	449 455	230 113	161 656
Lead	35	84	88
Copper	64	75	71
Zinc	100	1 133	1 219
Cadmium	9	2.5	1.1
Chromium	84	7	-14
Nickel	0	103	118
BOD	19 496	228 459	259 417
COD	0	752 091	822 891
Oil/grease	0	46 173	48 605
Bacteria, millions/100ml			
Fecal coliform	1.1	0.9	0.8
Fecal strep	0.0	3.9	4.7

BOD = biochemical oxygen demand; COD = chemical oxygen demand.
Note. The total area for each scenario is 3105 acres in Hunterdon County.

be constructed; however, 8000 condominium units could be built and 879 acres could be left in their current open-space condition. A comparison of these land use scenarios with current baseline conditions is shown in Table 1.

RESULTS

Estimated Impact

Estimates of total uncontrolled nonpoint source pollution loadings for 14 water-quality variables for these 2 development scenarios and existing baseline conditions are shown in Table 2. If either of these developments is built, we estimate substantial increases in the zinc, nickel, lead, BOD, COD, and oil/grease that will reach the nearby bodies of water. Notably, Table 2 also shows that the loadings do not vary much by residential-development density. Indeed, these density-related differences are within the expected predictive variance or error associated with the model. In essence, whereas pollution loadings did not differ for the various density options, loadings were vastly different for the development scenarios versus the baseline (undeveloped greenfields) condition.

Engineering Controls

Best management practices (BMPs) can mitigate the impact of development. The suitability of each BMP for a development is based on site considerations, such as slope, soil type, geology, water table depth, and development density. Each practice has certain advantages and disadvantages for each site. Nonstructural controls include zoning, open space retention, recharge-area protection, clustering, street sweeping, and public education. Structural (physical) controls include extended detention ponds (dry), wet ponds, infiltration trenches and basins, porous pavement, water-quality inlets, filter strips, and grassed swales. The most common structural control is either a wet or a dry pond; both have the potential for high pollutant removal if properly designed and maintained. Table 3 shows the potential for capturing unwanted contaminants across a variety of well-known BMPs. Individually or in combination, the BMPs have the potential to capture two thirds or more of the uncontrolled runoff. However, some BMPs could actually increase pollution. For example, nitrate nitrogen could increase with the application of surface sand filters and perimeter sand filters.

Many of the BMPs—especially ponds and detention basins—require substantial land. The 8-residential-units-per-acre option will accommodate them, but the lower-density configuration will not, because not enough land is available to fit in all the housing while preserving the acreage required for capturing the

TABLE 3—Estimated Pollutant Loading Reduction for Selected Best Management Practices

Best Management Practice	Total Phosphorus, %	Nitrate Nitrogen, %	Ammonia Nitrogen, %	Total Suspended Solids, %	Fecal Coliform, %	Metals, %
Extended detention basin	30	0	. . .	70	. . .	40
Wet pond	50	30	25	80	70[a]	60
Stormwater wetland	40	60	30	80	50[a]	60
Surface sand filter	50	Negative	. . .	80	40	40
Perimeter sand filter	60	Negative	70	80[b]	40	50
Bioretention system	60	. . .	50	80	. . .	80
Enhanced swale	30	50	50	60	. . .	40
Dry well	80	. . .	. . .	80	. . .	. . .
Pervious paving	50	. . .	. . .	60	. . .	60
Infiltration structure[c]	60	25	70	70	60	60
Filter strip	20	10	20	60	. . .	40
Riparian forest buffer	50	80	40	70	. . .	60

Source. Adapted from NJ Dept of Environmental Protection,[16] US Environmental Protection Agency,[17] and Scheuler.[18]
[a]If there is no resident waterfowl population.
[b]Needs pretreatment.
[c]With filter strip.

runoff. Hence, high density is required. Also, the BMPs' potential depends on proper maintenance and stewardship of the systems, which if not performed will quickly reduce the BMPs' effectiveness.

Institutional Smart Growth Options

Purchasing sensitive land or trading sensitive land for other land—especially if the redevelopable land can be part of a transit-oriented development—is desirable, because transit-oriented developments concentrate people and jobs around mass transit hubs rather than placing them on sensitive watershed lands. Our transit village proposal in Union County is not possible because of the county's already dense development. There is no single place where 8000 transit-oriented housing units can be placed. However, to illustrate the implications of what might be possible, we focused on 1 of Union County's larger and older cities—Plainfield—as a representative case study of the potential for residential redevelopment. Plainfield is an industrial suburb and commuter town that has suffered badly since the end of the World War II and has lost much of its middle-class population.[10]

We identified a 583-acre area along the rail corridor that is highly conducive to a mix of dense residential, small commercial, and retail redevelopment. The area is within walking distance of 2 train stations and thus would offer new residents an opportunity to reduce their reliance on automobiles to reach their jobs, the airport, and other conveniences. Our proposal includes redeveloping 15 of the 21 known brownfields within Plainfield.

If developed at the same density that we assumed in our Hunterdon County development scenario—8 units and 20 people per acre—the area could house about 11 600 people. If 30% of the land area used for parks and civic or community buildings were set aside to provide balance, this redevelopment zone could contain about 3265 new residential units and house about 8160 people. Allowing for some relocation of existing Plainfield residents into these new housing units would probably reduce the net impact to about 5000 to 6000 people, or about 25% to 30% of the expected population growth in Hunterdon County over the next 10 years.

Plainfield is only the eighth largest city in terms of land area and the third most populous in Union County. As such, it is reasonable to expect that redeveloping other brownfields and contiguous properties on a similar basis in multiple areas of the county could comfortably provide housing and services for more than half the people who might otherwise relocate on greenfields in Hunterdon County. In short, a series of transit-oriented, high-density developments in Union County would clean up brownfields, would not pollute public potable water supplies, and would help preserve open space around important reservoir and watershed areas in Hunterdon County.

DISCUSSION

Caveats regarding the Hunterdon County and Union County analyses must be noted. It is important to realize that the output of the Hunterdon County analysis is contaminant loadings. In other words, without water quality models, our results cannot be converted into concentrations of contaminants in the drinking-water supply, and our results certainly are not predictions of increased numbers of illnesses.

Nevertheless, it is appropriate to suggest what might happen in a worst-case scenario for public health and for better outcomes. Under the worst possible circumstance, even in this relatively pristine area, the runoff from an uncontrolled urban development, such as the scenarios we simulated, could lead to acute and chronic illnesses through drinking water, contact recreation, and fish consumption.[3,19] Pathogens, and hence serious waterborne outbreaks, could increase, as could less serious gastrointestinal infections, ear and eye infections, and skin rashes. With respect to chronic diseases, runoff could increase the carcinogenic, toxic metal, and hormonal disrupter burden in the exposed population. In short, without attempting to overamplify the risk, we consider it fair to say that this combination of acute and chronic public threats from uncontrolled runoff is a major challenge to our water supplies.[19,20] Perhaps we are engaging in wishful thinking, but we do not believe that the worst-case scenario will materialize in this watershed.

We brought our results to the attention of senior state officials and water purveyors whom we have known for many years. They were distressed; as a result, they have begun to increase sampling, and they will build a set of water quality models so that contaminant-loading estimates can be converted to concentrations in the water supply. More important, rather than wait for more data, they have begun to use their financial and political resources to preserve the parcels we have identified as highly sensitive. This action includes arguing that land-preservation funds should be prioritized for sensitive watersheds. Indeed, making the protection of these sensitive areas a priority was a recommendation given to Governor-elect James E. McGreevey by his Smart-Growth Transition Team, which M.G. cochaired. In short, the best public health outcome is that the land will be protected by the state and its local governments and that some of the people who would have moved to this area will relocate to transit-oriented developments.

A less favorable but plausible outcome is that the smart growth policies will fail, and much of the sensitive land will not be preserved. If this happens, we hope that engineering controls will be effectively deployed to control runoff. According to the New Jersey Department of Environmental Protection, treating stormwater runoff is estimated to cost between $2000 and $50 000 per water-impervious developed acre. The BMP costs are higher for small developments and decrease rapidly for larger areas.[16] Water purveyors should expect additional costs. For example, Oleg Kostin, superintendent of plant operations for the Elizabethtown Water Company, estimated that it would cost his company 5% to 10% more per year if the company's current raw water were to be degraded. The current cost for chemicals is about $1 million a year (personal communication, February 24, 2003).

With regard to the transit-oriented development part of smart growth, we have no incontrovertible data to show that people or businesses that would otherwise move to Hunterdon County would be willing to live in Union County on former brownfield sites. Yet, a recent survey of 800 New Jersey residents shows that this scenario is not implau-

sible.[21] Specifically, 14% of New Jersey residents said they both planned to move during the next 5 years and would move to a cleaned-up former brownfield site. Those who seem most likely to move to a transit-oriented development on a former brownfield site are young (average age=35 years), currently live in apartments, and want to improve the quality of their residences and their neighborhoods. Typically, their next move would be to a suburb like Hunterdon County. But many of the interested parties said that they already lived near a brownfield, and they perceived a cleaned-up site with brand-new housing as an opportunity to improve the quality of their lives without moving out of the area. Hence, our assumption that people who otherwise would move to sprawling suburbs might be willing to stay in new housing built on former brownfield sites is not far-fetched.

Environmental health and planning have a long and joint history of gathering data and then advocating action to protect public health on the basis of that data. Our study calls for the reappearance of "the ghost of urban redevelopment past" that resulted in the institution of zoning, the building of New York City's Central Park, the understanding that unbridled industrial growth in Pittsburgh was having a serious impact on the health of immigrant populations, and other urban policies of the late-19th and early-20th centuries that recognized that many design, planning, and public health problems are inexorably linked.[22] Environmental health must be a major consideration in land use and engineering decisions, in regional development planning, and in transportation planning. We need to act on the emerging evidence of environmental health benefits. ■

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Contributors

M. Greenberg organized and directed the study and prepared the article. H. Mayer co-directed the research and directed the Plainfield study. K.T. Miller obtained field data from Hunterdon County and performed the housing density computations. R. Hordon performed the runoff computations. D. Knee performed the GIS work for Hunterdon County.

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References

1. Tarr J. *The Search for the Ultimate Sink: Urban Pollution in Historical Perspective.* Akron, Oh: University of Akron Press; 1996.

2. Melosi M. *Effluent America: Cities, Industry, Energy, and the Environment.* Pittsburgh, Pa: University of Pittsburgh Press; 2001.

3. MacKenzie W, Hoxie N, Proctor M, Gradus M, Blair K, Peterson D. A massive outbreak in Milwaukee of *Cryptosporidium* infection transmitted through public water supply. *N Engl J Med.* 1994;331:161–167.

4. Dzurik A. *Water Resources Planning.* 2nd ed. New York, NY: Rowman and Littlefield; 1996.

5. Heisig P. Effects of residential and agricultural land uses on the chemical quality of baseflow of small streams in the Croton watershed, southeastern New York. US Geological Survey; 1999. WRIR 99–4173.

6. Zukin C. Environmental attitudes in New Jersey: treading dirty water [press release]. *Star-Ledger/Eagleton.* April 2, 2000.

7. Nieswand G, Hordon R, Shelton T, Chavooshian B, Blarr S. Buffer strips to protect water supply reservoirs. *Water Resources Bull.* 1990;26:959–966.

8. Fischel W. *The Economics of Zoning Laws: A Property Rights Approach to American Land Use Controls.* Baltimore, MD: Johns Hopkins University Press; 1985.

9. *Industry Employment Projections by Major Sector: 1990 B 2005.* Hunterdon County, NJ: Hunterdon Economic Partnership; 1999.

10. Hughes J, Seneca J. *Ranking Municipalities: Incomes and Housing Values.* New Brunswick, NJ: Edward J. Bloustein School of Planning and Public Policy; 1994.

11. Cevero R. *Transit-Oriented Development and Joint Development in the United States: A Literature Review.* Washington, DC: Transit Research Board of the National Academies; 2002.

12. Jablonski J, Wilson K, Berdanier C, Kirkham W, Johnson J. *Soil Survey of Hunterdon County, New Jersey.* Washington, DC: US Dept of Agriculture, Soil Conservation Service; 1974.

13. Hunterdon County Planning Board, GIS files for county provided to authors, 2001.

14. http://danpatch.ecn.purdue.edu/-sprawl/LTHIA.

15. US Environmental Protection Agency. *Drinking Water Contaminants.* Available at: http://www.epa.gov/safewater/hfactrs.html. Accessed January 21, 2003.

16. *Revised Manual for New Jersey: Best Management Practices for Control of Nonpoint Source Pollution from Stormwater.* Trenton, NJ: NJ Dept of Environmental Protection; 2000.

17. *Preliminary Data Summary of Urban Stormwater Best Management Practices.* Washington, DC: US Environmental Protection Agency; 1999. EPA report 821–R–99–012.

18. Schueler T. *Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs.* Washington, DC: Metropolitan Washington Council of Governments; 1987.

19. *National Water Quality Inventory: 2000 Report.* Washington, DC: US Environmental Protection Agency; 2000. EPA Report 841–R–02–001.

20. Levin R, Epstein P, Ford T, Harrington W, Olson E, Reichard E. US drinking water challenges in the twenty-first century. *Environ Health Perspect.* 2002; 110(suppl 1):43–52.

21. Greenberg M, Craighill P, Mayer H, Zukin C, Wells J. Brownfield redevelopment and affordable housing: a case study of New Jersey. *Housing Policy Debate.* 2001;12(3):703–711.

22. Greenberg M, Popper F, West B, Krueckeberg D. Linking city planning and public health in the United States. *J Plann Lit.* 1994;8:235–239.

Public Health Effects of Inadequately Managed Stormwater Runoff

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Objectives. This study investigated the scale of the public health risk from stormwater runoff caused by urbanization.

Methods. We compiled turbidity data for municipal treated drinking water as an indication of potential risk in selected US cities and compared estimated costs of waterborne disease and preventive measures.

Results. Turbidity levels in other US cities were similar to those linked to illnesses in Milwaukee, Wis, and Philadelphia, Pa. The estimated annual cost of waterborne illness is comparable to the long-term capital investment needed for improved drinking water treatment and stormwater management.

Conclusions. Although additional data on cost and effectiveness are needed, stormwater management to minimize runoff and associated pollution appears to make sense for protecting public health at the least cost. (*Am J Public Health.* 2003;93:1527–1533)

Residents in the United States generally can depend on safe water for drinking, food production, and recreation, thanks to effective water treatment and protective environmental policies. Despite these safeguards, waterborne illnesses are prevalent and may increase because of the strain of climate change, population growth, and changing land use.[1] Expansion of urban areas is creating more impervious surfaces, such as roofs, roads, and parking lots, that collect pathogens, metals, sediment, and chemical pollutants and quickly transmit them to receiving waters during rain and snowmelt events. This nonpoint source pollution is one of the major threats to water quality in the United States[2] and is linked to chronic and acute illnesses from exposure through drinking water, seafood, and contact recreation. Impervious surfaces also lead to pooling of stormwater, increasing potential breeding areas for mosquitoes, the disease vectors for dengue hemorrhagic fever, West Nile virus, and other infectious diseases.

Traditional strategies to manage stormwater and treat drinking water require large infrastructure investments and face difficult technical challenges. Reducing stormwater runoff and associated nonpoint source pollution is a potentially valuable component of an integrated strategy to protect public health at the least cost.

WATERBORNE DISEASE

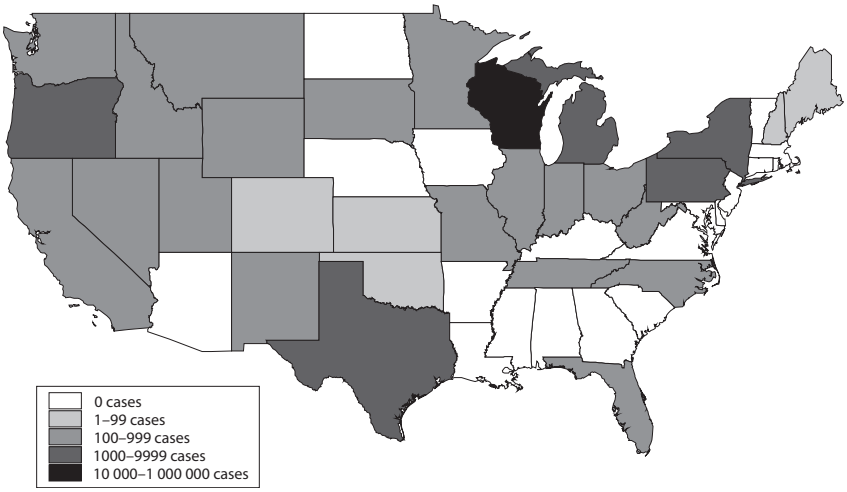
Acute illnesses can result from consuming water contaminated with protozoan oocysts, viruses, and bacteria. Between 1991 and 2000, 123 documented outbreaks of waterborne illness in 30 states were linked to pathogens or involved acute gastrointestinal illnesses of unknown etiology (Figure 1).[3–7] Pathogens currently impair 5529 US water bodies (Figure 2) and are the second leading cause of impairment, following sediment.[8] Children, the elderly, pregnant women, and the immunocompromised—20% of the US population—are at the greatest risk for serious illness and mortality from waterborne pathogens.[9] Outbreaks of cryptosporidiosis in Milwaukee, Wis, in 1993 and Las Vegas, Nev, in 1994 caused at least 70 fatalities among the immunocompromised.[4,10–12]

It is widely recognized that the vast majority of waterborne disease cases go unreported because of difficulties in diagnosing the cause of illness. Approximately 99 million people in the United States have acute gastrointestinal illnesses each year, at a cost of billions of dollars,[13] and 6% to 40% of these illnesses may be caused by contaminated drinking water.[1,14,15] Exposure to *Cryptosporidium* is common; 17% to 32% of people tested have evidence of infection by young adulthood.[16]

Drinking water outbreaks have been linked to runoff; more than half of the documented waterborne disease outbreaks since 1948 have followed extreme rainfalls.[17] Spring rains and snowmelt preceded the Milwaukee *Cryptosporidium* outbreak and may have played a role in transport of the oocysts.[6] Urban and suburban streets, parking lots, and lawns generate large loads of bacteria in stormwater,[18–20] and urban runoff is responsible for an estimated 47% of the pathogen contamination of Long Island Sound.[21] Stormwater drainage pipelines and channels accumulate sediment and block sunlight, inhibiting natural bacteria die-off and creating a bacterial reservoir,[22,23] and combined storm and sanitary sewer systems discharge untreated sewage into receiving waters when runoff volumes overwhelm their treatment capacity.

Inflows of runoff to surface water bodies, indicated by increased turbidity from suspended soil particles eroded from the landscape, are associated with elevated concentrations of bacteria, *Giardia*, *Cryptosporidium*, and other microorganisms.[24,25] Small increases in the turbidity of treated drinking water have been linked to increased occurrence of acute gastrointestinal illnesses among children and the elderly in Milwaukee and Philadelphia, Pa, even though the water is in compliance with Environmental Protection Agency standards.[26–28]

Fecal coliform bacteria in surface waters commonly exceed standards for recreation,[29] and exposure to bacteria and parasites from swimming and other forms of recreation in water contaminated with urban runoff has caused numerous cases of illness, including ear and eye discharges, skin rashes, and gastrointestinal problems.[30–32] Consumption of seafood from contaminated waters is linked to diarrheal and paralytic illnesses caused by the hepatitis A and Norwalk viruses, *Vibrio* species, and marine biotoxins formed by algal blooms.[31,33–36] Excess nitrogen from urban



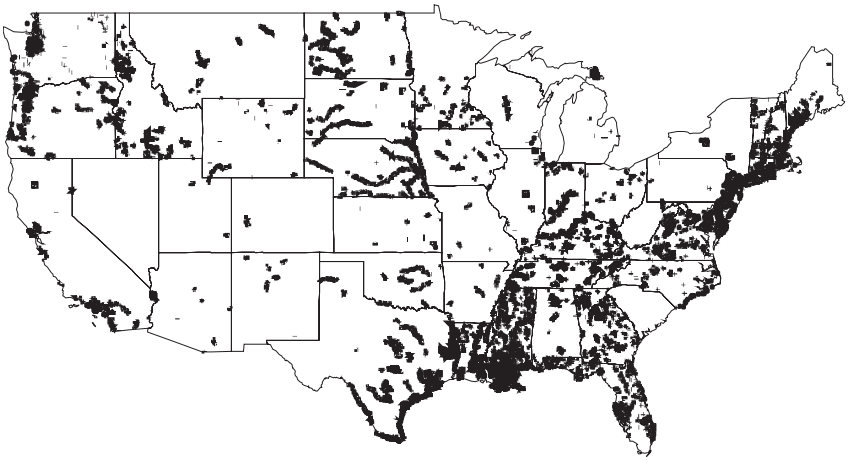
Note. Wisconsin reported the maximum number of cases, with 403 000 caused by the cryptosporidiosis outbreak of 1993.
Source. Compiled from Centers for Disease Control and Prevention data.[3-7]

FIGURE 1—Reported waterborne illnesses linked to pathogens or involving gastrointestinal illnesses of unknown etiology, 1991–2000.

and agricultural sources exacerbates harmful algal blooms.[37] Major sources of nitrogen from urban and suburban areas may include fertilizers carried by stormwater, vehicle exhaust, and septic systems.[38,39]

Nitrogen also poses direct health threats. Exposure to nitrate in drinking water increases the risk of methemoglobinemia, causing shortness of breath and blueness of the skin, especially for infants.[40,41] Consumption of water with elevated nitrate is also suspected to increase miscarriage risk.[42]

Various pollutants are commonly found in urban and suburban stormwater. Runoff from roofs, roads, and parking lots can contain significant concentrations of copper, zinc, and lead,[19,38] which can have toxic effects in humans. Insecticides occur widely in sediment and fish in urban streams at levels considered harmful to wildlife,[43] raising concerns about carcinogenic effects and disruption of hormonal systems in humans.[44] Increased traffic volume in recent decades has resulted in higher concentrations of polyaromatic hydrocarbons—known human carcinogens—in urban lake sediments, with concentrations commonly exceeding levels set to protect aquatic ecosystems.[45]



Source. Compiled from US Environmental Protection Agency data.[8]

FIGURE 2—Pathogen-impaired water bodies, 1998–2000.

DRINKING WATER TREATMENT

Community drinking water supplies are commonly disinfected with chlorine and, if the source is surface water, filtered to remove sediment and associated pollutants. Several common microorganisms, including *Cryptosporidium*, are resistant to treatment with chlorine and filtration,[46] although the effectiveness of filters varies with their pore size. Suspended sediment in source waters further reduces the effectiveness of chlorine. A 1995 study found that 13% of the samples of drinking water filtered and treated with chlorine still contained *Cryptosporidium* oocysts.[47] Ozone is increasingly being used for disinfection instead of or in addition to chlorine. High ozone doses can inactivate *Giardia* and *Cryptosporidium*; however, neutralizing the ozone after treatment presents technical difficulties, and addition of ozone to water containing bromide can form bromate, a potential human carcinogen.[48]

The need for disinfection must be weighed against growing evidence of carcinogenic and other health effects related to disinfection byproducts. Trihalomethanes and other disinfection byproducts form when chlorine reacts with organic carbon associated with sediment or produced by algal and bacterial growth, which can be enhanced by nitrogen and phosphorous in runoff.[49] The Environmental Protection Agency estimates that ingestion of disinfection byproducts in drinking water leads to 1100 to 9300 cases of bladder cancer each year,[50] and trihalomethanes are linked to neural tube defects, small size for gestational age, and spontaneous abortions.[51]

Approximately 42 million people in rural and suburban areas use their own private water supplies, typically shallow groundwater wells that are not covered by the Safe Drink-

ing Water Act and are rarely treated or monitored.[52] Concerns include cross-contamination from runoff and surface water and contamination by nitrates and pathogens from septic systems.

EFFECTS OF COMMUNITY DESIGN

Community design has a major effect on stormwater volumes and quality, as well as treatment methods and costs. The total area of impervious surfaces in a community is 1 of the most common measures used to assess the effects of community design on stormwater runoff.[53] Also important is the degree of connection between impervious surfaces and the storm drainage system; surfaces that drain directly to vegetated areas produce less runoff and are considered to have a lower effective impervious area.

Urbanization of the landscape adds to strain on water resources by expanding the area covered by impervious surfaces that shed virtually all rainfall and snowmelt. Hydrologic models predict large increases in runoff for urbanizing areas,[54,55] with runoff volume increasing linearly with impervious surface area.[56] Long-term stream-flow monitoring has shown that development leads to higher flood peaks[57] and to increases in annual runoff volumes of 2 to 4 times previous levels for suburban areas and 15 times previous levels for highly urban areas.[58,59]

Increased runoff volume generates greater pollutant loads.[60] In response to an 18% increase in urban area in a watershed near Indianapolis, Ind, between 1973 and 1991, annual average runoff volume increased by 80%, and average annual loads for lead, copper, and zinc increased by more than 50%.[61] High proportions of urban land cover and steep slopes—predictors of high runoff volumes—correspond with high fecal coliform levels in South Carolina watersheds.[62] Elevated fecal coliform levels also have been detected in suburban streams.[63]

Although low-density development with large lawns leads to a low proportion of impervious cover within individual lots, the total impervious surface area of low-density residential and commercial developments, on the regional scale, is typically much larger than that of higher-density developments.[64,65] This high proportion of impervious surface area is largely a result of roads and parking lots, which can account for more than 60% of a low-density development's impervious area.[66] Although large lawns might seem capable of absorbing runoff from adjacent surfaces, they are typically compacted by construction equipment and can generate up to 90% as much runoff as pavement.[67,68] Runoff measured from suburban developments has been shown to be 1.5 to 4 times greater than that from rural areas,[69,70] although low-density development may produce less runoff than do some intensive agricultural land uses.[71]

Moreover, construction of low-density developments disturbs the soil over larger land areas, accelerating transport of sediment and associated pollutants into water bodies. Stripping the protective vegetation cover from construction sites accelerates soil erosion to a rate up to 40 000 times higher than before the soil was disturbed.[72] During brief periods of active construction, sediment yield from watersheds can increase 5-fold, with additional deposition in stream channels providing a continual sediment source during subsequent storms.[73] This accumulated sediment can harbor large populations of bacteria and other pathogens.[74]

There is widespread concern that increased runoff from impervious surfaces contributes to the depletion of groundwater aquifers. Unfortunately, few detailed studies of urban groundwater recharge have been performed to evaluate this concern. Leaks from aging water distribution networks and infiltration in stormwater ponds and channels may add appreciably to aquifer recharge.[75] However, infiltration ponds have a high failure rate because of fine sediment that settles to the bottom and forms a hydraulic barrier,[76] and improvements in construction materials for water pipelines probably lead to reduced leakage in new developments.[77] Nearly half of the US population drinks groundwater from wells,[52] and widespread drops in groundwater levels have contributed to water quality problems, including increased arsenic concentrations.[78]

METHODS

Because turbidity is an indicator of runoff and was associated with increased illness in Milwaukee and Philadelphia,[26–28] we compiled turbidity data for treated drinking water of selected cities in 2001 for comparison. We obtained this information from annual consumer confidence reports published by each water utility. Many of these systems reported turbidity values for water mixed from multiple sources and treatment facilities.

An important consideration in deciding how to address waterborne illness is the cost associated with different options. Unfortunately, available data are inadequate to fully assess these costs. In this article, we present estimates of some of the costs associated with (1) managing current levels of waterborne illness, (2) improving drinking water treatment, and (3) improving stormwater management. Although incomplete, such estimates illustrate the magnitude of these costs and underscore important unanswered questions.

We estimated the annual cost of gastrointestinal illnesses related to drinking water by multiplying the estimated cost of all infectious gastrointestinal illnesses for 1985[13] by the fraction of these illnesses (6%–40%) attributed to drinking water in the literature.[1] Cost estimates for drinking water treatment and stormwater management were taken from Environmental Protection Agency surveys of 20-year capital investment needs.[79,80] We did not extrapolate the annual cost of illness over the same 20-year period, because this estimate was based on data from only 1 year. All costs were converted to 2002 dollars.

RESULTS

Table 1 lists annual minimum, mean, and maximum turbidity values based on daily samples of treated drinking water for selected cities. All of these systems were in compliance with the Environmental Protection Agency requirements in effect at that time that no sample exceed a turbidity of 5 nephelometric turbidity units and that no more than 5% of daily samples show turbidity greater than 0.5 nephelometric turbidity unit. In 2002, these standards were reduced to 1 nephelometric turbidity unit and 0.3 nephelometric turbidity unit, respectively.

The low and high estimates of the annual cost of gastrointestinal illnesses related to drinking water (Table 2) differ by nearly a

TABLE 1—Turbidity Values for Treated Drinking Water Reported by Selected Cities for 2001

City/Treatment System	Drinking Water Turbidity (NTU) Minimum	Maximum	Mean
Ann Arbor, Mich	NR	0.2	NR
Atlanta, Ga	NR	>0.5	NR
Austin, Tex	0.01	0.34	0.08
Baltimore, Md			
Ashburton filtration plant	NR	0.39	NR
Montebello filtration plants	NR	0.41	NR
Chicago, Ill	NR	NR	0.34
Corvallis, Ore	0.02	0.08	0.04
Dallas, Tex	0.04	0.2	0.08
Denver, Colo			
Marston filtration plant	<0.05	0.07	0.04
Foothills filtration plant	0.04	0.05	0.04
Moffat filtration plant	0.04	0.07	0.05
Detroit, Mich	NR	0.48	NR
Houston, Tex, main system	<0.01	0.5	0.07
Los Angeles, Calif			
Los Angeles Aqueduct filtration plant	0.1	0.37	0.12
Diemer filtration plant	0.05	0.07	0.06
Weymouth filtration plant	0.06	0.08	0.07
Milwaukee, Wis	0.06	0.23	0.08
New York, NY			
Catskill–Delaware system	0.8	1.7	1.1
Croton system	1.3	1.6	1.4
Philadelphia, Pa	NR	0.08	0.06
Seattle, Wash			
Cedar system	0.3	3.9	0.8
Tolt system	0.04	0.3	0.07
Washington, DC	NR	0.19	NR

Note. NTU = nephelometric turbidity unit; NR = not reported.

TABLE 2—Comparison of Costs of Options for Addressing Waterborne Illness

Option	Estimate	Cost, in Billions of 2002 Dollars	Source
Continue to manage waterborne illnesses	Annual cost of waterborne gastrointestinal illnesses	2.1–13.8[a]	Estimate of total cost of endemic gastrointestinal illness in 1985[13] and range of these illnesses attributed to drinking water[1]
Improve drinking water treatment	20-year capital needs to meet current and proposed drinking water standards	33.0[b]	1999 Drinking Water Infrastructure Needs Survey[79]; "regulatory needs" for compliance with current and future regulations
Improve stormwater management	20-year capital needs for runoff control	9.3[c]	1996 Clean Water Needs Survey[80]; categories VI (stormwater) and VIID (urban runoff)

[a]Adjusted for inflation by multiplying by factor of 1.50.
[b]Adjusted for inflation by multiplying by factor of 1.06.
[c]Adjusted for inflation by multiplying by factor of 1.11.

factor of 10 because of uncertainty in identifying the cause of illness. These estimates do not include other acute effects, chronic illnesses, or illnesses related to recreation or consumption of contaminated seafood or produce. The higher estimate is comparable to the 20-year capital costs for enhanced drinking water treatment and stormwater management. Operation and maintenance over the 20-year period are not included in these estimates; however, a reasonable assumption is that these costs will be similar to the capital investment.[81,82]

DISCUSSION

Although it is highly likely that Figure 1 greatly underestimates the burden of disease caused by waterborne pathogens, it does indicate widespread occurrence of such disease. Because of underreporting issues and the poor geographic resolution of the state-level illness data, it is difficult to directly compare Figures 1 and 2.

The turbidity of drinking water in many US cities (Table 1) is similar to the level of turbidity linked to illnesses in Milwaukee and Philadelphia (where the mean turbidity was <0.2 nephelometric turbidity unit).[26–28] Although these data alone are insufficient to define the level of risk, they underscore the need for additional research into the complex relations between turbidity, pathogen loads, drinking water treatment, and illness. Assessment of risk and early warning of contamination would be greatly aided by more rapid and accurate testing methods for microbiological contaminants.[83]

Given the limited information in Table 2, the costs of drinking water treatment and stormwater management appear reasonable compared with the burden of waterborne illness. The economic benefits of drinking water treatment have been established previously.[84] Better data regarding the cost and effectiveness of stormwater management options as well as on the true cost of waterborne illness are needed to make fully informed decisions.

Conventional urban stormwater management requires a large investment in infrastructure. For example, the Milwaukee Metropolitan Sewage District has reduced, but not eliminated, combined sewer overflows since 1994 by spending $716 million to construct a tunnel to store excess stormwater during runoff events, allowing it to be treated later.[85] Consequently, it makes sense to use alternative strategies that reduce the volume and improve the quality of stormwater. Planning on the regional scale that integrates community design and watershed function can reduce stormwater volumes and effects. On the local scale, further reduction can be achieved through compact site design and best management practices that remove pollutants, detain stormwater, and reduce runoff volume by enhancing infiltration into the soil.

Watershed planning strategies that effectively protect water quality include maintaining vegetated buffer strips and setback distances of at least 150 m for impervious areas

along water bodies[63,86] and preserving forests and other highly pervious land covers.[87] New York City has chosen to spend $1.4 billion over 10 years as part of a strategy to protect its Catskill–Delaware water supply by purchasing land as a buffer against development, thus avoiding the need for a filtration plant that would cost $6 billion to construct and would have an annual operating cost of $300 million.[88,89]

Compact site designs include narrow streets, reduced parking requirements, mixed land uses, increased residential densities, and open space. The city of Olympia, Wash, determined that a 20% reduction in impervious area would not require exceptional changes.[66] A stormwater ordinance passed by the city of Columbus, Ohio, includes reducing street widths and commercial parking to minimize impervious surfaces and enhance open space.[90] Runoff simulations of proposed community designs suggest that a compact development with significant open space may generate only half the increased stormwater volume generated by a conventional, large-lot development.[91]

Best management practices can reduce but not eliminate pollutant loadings of common stormwater pollutants. Designs that collect runoff and allow it to infiltrate the soil have the highest documented pollutant-removal efficiency, eliminating nearly all lead, zinc, and solids and more than 50% of total nitrogen and phosphorus. Ponds and wetlands, which allow contaminants to settle out of the water column or be broken down by sunlight and biological activity, can remove more than 70% of bacteria but are less effective for other pollutants. Drainage ditches and swales appear to have very limited pollutant-removal capabilities.[92] Pollutant modeling indicates that street sweeping once a week on highways and every 3 days in residential areas removes 10% to 60% of solids and nutrients.[93] Modern street sweepers that use vacuum systems may result in higher and more consistent pollutant-removal effectiveness, although potential negative side effects, such as air and noise pollution, also must be considered. Managing urban pet and wildlife waste may reduce pathogen loads, although more research on parasite and bacteria infection rates in animals is needed.[83]

Low-impact development techniques are gaining popularity for supplementing traditional best management practices and reducing infrastructure needs. Low-impact development measures route runoff from impervious surfaces to natural or constructed features where it can infiltrate the soil. Connecting roof drains to a yard, garden, or infiltration trench can double the amount of precipitation that infiltrates the soil.[94] Diverting roof downspouts from sanitary sewers to yards in a Michigan community reduced storm flows in sewers by 25% to 62%, resulting in cost savings that matched the cost of the conversion in only 2 months.[95] Buildings with green roofs (roofs covered with soil and live vegetation to absorb precipitation) have been used for years in Europe and have been successfully constructed in the United States.

Protecting public health by reducing urban stormwater runoff and associated nonpoint source pollution makes sense as a complement to water treatment infrastructure and health care interventions. In fact, stormwater management needs to be integrated into a comprehensive water management scheme that addresses water supply and sewage treatment. We believe that such integrated programs are necessary to adequately protect public health at the lowest cost. ■

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Contributors

S.J. Gaffield led the design and implementation of the study and the writing of the article. R.L. Goo helped to conceptualize ideas, plan the analysis, and write the article. L.A. Richards assisted with the literature review, study design, and writing of the article. R.J. Jackson conceived of this article and assisted with planning and writing.

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No human participants were involved in this study.

References

1. Levin RB, Epstein PR, Ford TE, Harrington W, Olson E, Reichard EG. US drinking water challenges in the twenty-first century. *Environ Health Perspect.* 2002; 110(suppl 1):43–52.

2. *National Water Quality Inventory: 2000 Report.* Washington, DC: US Environmental Protection Agency; 2000. Report EPA-841-R-02-001.

3. Moore AC, Herwaldt BL, Craun GF, Calderon RL, Highsmith AK, Juranek DD. Surveillance for waterborne disease outbreaks—United States, 1991–1992. *MMWR CDC Surveill Summ.* 1993;42(SS-5):1–22.

4. Kramer MH, Herwaldt BL, Craun GF, Calderon RL, Juranek DD. Surveillance for waterborne-disease outbreaks—United States, 1993–1994. *MMWR CDC Surveill Summ.* 1996;45(SS-1):1–33.

5. Levy DA, Bens MS, Craun GF, Calderon RL, Herwaldt BL. Surveillance for waterborne-disease outbreaks—United States, 1995–1996. *MMWR CDC Surveill Summ.* 1998;47(SS-5):1–34.

6. Barwick RS, Levy DA, Craun GF, Beach MJ, Calderon RL. Surveillance for waterborne-disease outbreaks—United States, 1997–1998. *MMWR CDC Surveill Summ.* 2000;49(SS-4):1–35.

7. Lee SH, Levy DA, Craun GF, Beach MJ, Calderon RL. Surveillance for waterborne-disease outbreaks—United States, 1999–2000. *MMWR CDC Surveill Summ.* 2002;51(SS-8):1–28.

8. US Environmental Protection Agency. National Section 303(d) List Fact Sheet [report online]; 2002. Available at: http://oaspub.epa.gov/waters/national_rept.control. Accessed December 13, 2002.

9. Gerba CP, Rose JB, Haas CN. Sensitive populations: who is at the greatest risk? *Int J Food Microbiol.* 1996;30(1–2):113–123.

10. MacKenzie WR, Hoxie NJ, Proctor ME, et al. A massive outbreak in Milwaukee of Cryptosporidium infection transmitted through public water supply. *N Engl J Med.* 1994;331:161–167.

11. Hoxie NJ, Davis JP, Vergeront JM, Nashold RD, Blair KA. Cryptosporidiosis-associated mortality following a massive waterborne outbreak in Milwaukee, Wisconsin. *Am J Public Health.* 1997;87:2032–2035.

12. Goldstein ST, Juranek DD, Ravenholt O, et al. Cryptosporidiosis: an outbreak associated with drinking water despite state-of-the-art water treatment. *Ann Intern Med.* 1996;124:459–468.

13. Garthright WE, Archer DL, Kvenberg JE. Estimates of incidence and costs of intestinal infectious diseases in the United States. *Public Health Rep.* 1988; 103:107–115.

14. Payment P, Richardson L, Siemiatycki J, Dewar R,

Edwardes M, Franco E. A randomized trial to evaluate the risk of gastrointestinal disease due to consumption of drinking water meeting current microbiological standards. *Am J Public Health.* 1991;81:703–708.

15. Chute CG, Smith RP, Baron JA. Risk factors for endemic giardiasis. *Am J Public Health.* 1987;77: 585–587.

16. Guerrant RL. Cryptosporidiosis: an emerging, highly infectious threat. *Emerg Infect Dis.* 1997;3: 51–57.

17. Curriero FC, Patz JA, Rose JB, Lele SD. The association between extreme precipitation and waterborne disease outbreaks in the United States, 1948–1994. *Am J Public Health.* 2001;91:1194–1199.

18. Olivieri VP, Kruse CW, Kawata K. Selected pathogenic microorganisms contributed from urban watersheds. In: Correll DL, ed. *Watershed Research in North America: A Workshop to Compare Results.* Vol 2. Edgewater, Md: Smithsonian Institution, Chesapeake Bay Center for Environmental Studies; 1977:635–661.

19. Bannerman RT, Owens DW, Dodds RB, Hornewer NJ. Sources of pollutants in Wisconsin stormwater. *Water Sci Technol.* 1993;28(3–5): 241–259.

20. Young KD, Thackston EL. Housing density and bacterial loading in urban streams. *J Environ Eng.* 1999;125:1177–1180.

21. *Long Island Sound Study: Summary of the Comprehensive Conservation and Management Plan.* Stamford, Conn: US Environmental Protection Agency; 1994. Report EPA-842-S-94-001.

22. Occoquan Watershed Monitoring Lab. *Fecal Coliform Counts in Stream Sections in Below-Ground Culverts: A Report Submitted to the Northern Virginia Regional Commission.* Manassas: Virginia Polytechnic Institute and State University; 2002.

23. Marino RP, Gannon JJ. Survival of fecal coliforms and fecal streptococci in storm drain sediment. *Water Res.* 1991;25:1089–1098.

24. Atherholt TB, LeChevallier MW, Norton WD, Rosen JS. Effect of rainfall on Giardia and Cryptosporidium. *J Am Water Works Assoc.* 1998;90(9):66–80.

25. Gannon JJ, Busse MK. E. coli and enterococci levels in urban stormwater, river water and chlorinated treatment plant effluent. *Water Res.* 1989;23: 1167–1176.

26. Morris RD, Naumova EN, Levin R, Munasinghe RL. Temporal variation in drinking water turbidity and diagnosed gastroenteritis in Milwaukee. *Am J Public Health.* 1996;86:237–239.

27. Schwartz J, Levin R, Hodge K. Drinking water turbidity and pediatric hospital use for gastrointestinal illness in Philadelphia. *Epidemiology.* 1997;8:615–620.

28. Schwartz J, Levin R, Goldstein R. Drinking water turbidity and gastrointestinal illness in the elderly of Philadelphia. *J Epidemiol Community Health.* 2000;54: 45–51.

29. *Selected Findings and Current Perspectives on Urban and Agricultural Water Quality by the National Water-Quality Assessment Program.* Reston, Va: US Geological Survey; 2001. Fact Sheet FS-047–01.

30. Dufour AP. *Freshwater Recreational Water Quality and Swimming-Associated Illnesses: Proceedings of the 2nd National Symposium on Municipal Wastewater Disinfection.* Cincinnati, Ohio: US Environmental Protection Agency; 1983. Report EPA-600-*-9-83-009.

31. Rose JB, Epstein PR, Lipp EK, Sherman BH, Bernard SM, Patz JA. Climate variability and change in the United States: potential impacts on water- and foodborne diseases caused by microbiologic agents. *Environ Health Perspect.* 2001;109(suppl 2):211–221.

32. Haile RW, Alamillo J, Barrett K, et al. *An Epidemiological Study of Possible Adverse Health Effects of Swimming in Santa Monica Bay: Final Report.* Santa Monica, Calif: Santa Monica Bay Restoration Project; 1996.

33. Craun GF. Waterborne disease outbreaks in the United States of America: causes and prevention. *World Health Stat Q.* 1992;45:192–199.

34. Centers for Disease Control and Prevention. Paralytic shellfish poisoning—Massachusetts and Alaska, 1990 [published erratum appears in *MMWR Morb Mortal Wkly Rep.* 1991;40(14):242]. *MMWR Morb Mortal Wkly Rep.* 1991;40(10):157–161.

35. Centers for Disease Control and Prevention. Multistate outbreak of viral gastroenteritis related to consumption of oysters—Louisiana, Maryland, Mississippi, and North Carolina. *MMWR Morb Mortal Wkly Rep.* 1993;42(49):945–948.

36. Epstein PR, Ford TE, Colwell RR. Marine ecosystems. *Lancet.* 1993;342:1216–1219.

37. National Research Council. *Clean Coastal Waters: Understanding and Reducing the Effects of Nutrient Pollution.* Washington, DC: National Academy Press; 2000.

38. Whipple W, Grigg S, Gizzard T, Randall CW, Shubinski RP, Tucker LS. *Stormwater Management in Urbanizing Areas.* Englewood Cliffs, NJ: Prentice-Hall; 1983.

39. Wernick BG, Cook KE, Schreier H. Land use and streamwater nitrate-N dynamics in an urban-rural fringe watershed. *J Am Water Resources Assoc.* 1998; 34:639–650.

40. Integrated Risk Information System (IRIS) [database online]. Cincinnati, Ohio: US Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment. Available at: http://www.epa.gov/ngispgm3/iris/index.html. Accessed December 9, 2002.

41. *National Primary Drinking Water Regulations Technical Fact Sheets.* Washington, DC: US Environmental Protection Agency, Office of Water, Office of Ground Water and Drinking Water; 1999.

42. Centers for Disease Control and Prevention. Spontaneous abortions possibly related to ingestion of nitrate contaminated well water—LaGrange County, Indiana, 1991–1994. *MMWR Morb Mortal Wkly Rep.* 1996;45(26):569–572.

43. *The Quality of Our Nation's Waters—Nutrients and Pesticides.* Reston, Va: US Geological Survey; 1999. Circular 1225.

44. National Research Council. *Hormonally Active Agents in the Environment.* Washington, DC: National Academy Press; 1999.

45. Van Metre PC, Mahler BJ, Furlong ET. Urban sprawl leaves its PAH signature. *Environ Sci Technol.* 2000;34:4064–4070.

46. Steiner TS, Thielman NM, Guerrant RL. Protozoal agents: what are the dangers for the public water supply? *Annu Rev Med.* 1997;48:329–340.

47. LeChevallier MW, Norton WD. Giardia and Cryptosporidium in raw and finished water. *J Am Water Works Assoc.* 1995;87(9):54–68.

48. National Research Council. *Identifying Future Drinking Water Contaminants.* Washington, DC: National Academy Press; 1999.

49. National Research Council. *Watershed Management for Potable Water Supply: Assessing the New York City Strategy.* Washington, DC: National Academy Press; 2000.

50. *Quantification of Cancer Risk From Exposure to Chlorinated Water.* Washington, DC: US Environmental Protection Agency, Office of Science and Technology, Office of Water; 1998.

51. Bove F, Shim Y, Zeitz P. Drinking water contaminants and adverse pregnancy outcomes: a review. *Environ Health Perspect.* 2002;110(suppl 1):61–74.

52. Solley WB, Pierce RR, Perlman HA. *Estimated Use of Water in the United States in 1995.* Reston, Va: US Geological Survey; 1998. Circular 1200.

53. Arnold CL, Gibbons CJ. Impervious surface coverage: the emergence of a key environmental indicator. *J Am Plann Assoc.* 1996;62:243–258.

54. Brun SE, Band LE. Simulating runoff behavior in an urbanizing watershed. *Comput Environ Urban Syst.* 2000;24:5–22.

55. Grove M, Harbor J, Engel B, Muthukrishnan S. Impacts of urbanization on surface hydrology, Little Eagle Creek, Indiana, and analysis of L-THIA model sensitivity to data resolution. *Phys Geography.* 2001; 22:135–153.

56. Bhaduri B, Minner M, Tatalovich S, Harbor J. Long-term hydrologic impact of urbanization: a tale of two models. *J Water Resources Plann Manage.* 2001; 127:13–19.

57. *Urbanization and Streams: Studies of Hydrologic Impacts.* Washington, DC: US Environmental Protection Agency; 1997. Report EPA-841-R-97-009.

58. Spinello AG, Simmons DL. *Base Flow of 10 South-Shore Streams, Long Island, New York, 1976–85, and the Effects of Urbanization on Base Flow and Flow Duration.* Reston, Va: US Geological Survey; 1992. Water-Resources Investigations Report 90-4205.

59. Burges SJ, Wigmosta MS, Meena JM. Hydrological effects of land-use change in a zero-order catchment. *J Hydrologic Eng.* 1998;3(2):86–97.

60. Charbeneau RJ, Barrett ME. Evaluation of methods for estimating stormwater pollutant loads. *Water Environ Res.* 1998;70:1295–1302.

61. Bhaduri B, Harbor J, Engel B, Grove M. Assessing watershed-scale long-term hydrologic impacts of land-use change using a GIS–NPS model. *Environ Manage.* 2000;26:643–658.

62. Smith JH, Wickham JD, Norton D, Wade TG, Jones KB. Utilization of landscape indicators to model potential pathogen impaired waters. *J Am Water Resources Assoc.* 2001;37:805–814.

63. Mallin MA, Wheeler TL. Nutrient and fecal coliform discharge from coastal North Carolina golf courses. *J Environ Qual.* 2000;29:979–986.

64. Zielinski J. The benefits of better site design in residential subdivisions. In: Schueler TR, Holland HK, eds. *The Practice of Watershed Protection.* Ellicott City, Md: Center for Watershed Protection; 2000:11–24.

65. Zielinski J. The benefits of better site design in commercial development. In: Schueler TR, Holland HK, eds. *The Practice of Watershed Protection.* Ellicott City, Md: Center for Watershed Protection; 2000: 25–34.

66. *Impervious Surface Reduction Study: Technical and Policy Analysis: Final Report.* Olympia, Wash: City of Olympia, Public Works Department; 1995.

67. Legg A, Bannerman R, Panuska J. *Variation in the Relation of Rainfall to Runoff From Residential Lawns in Madison, Wisconsin, July and August, 1995.* Madison, Wis: US Geological Survey; 1996. Water-Resources Investigation Report 96-4194.

68. Wignosta M, Burges S, Meena J. *Modeling and Monitoring to Predict Spatial and Temporal Hydrological Characteristics in Small Catchments.* Seattle: University of Washington, Dept of Civil Engineering; 1994. Water Resources Series Technical Report 137.

69. Buttle JM, Xu F. Snowmelt runoff in suburban environments (Ontario, Canada). *Nordic Hydrology.* 1988; 19:19–40.

70. Stephenson D. Comparison of the water balance for an undeveloped and a suburban catchment. *Hydrological Sci J.* 1994;39:295–307.

71. Liu AJ, Tong ST, Goodrich JA. Land use as a mitigation strategy for the water-quality impacts of global warming: a scenario analysis on two watersheds in the Ohio River Basin. *Environ Eng Policy.* 2000;2:65–76.

72. Harbor J. Engineering geomorphology at the cutting edge of land disturbance: erosion and sediment control on construction sites. *Geomorphology.* 1999; 31(1–4):247–263.

73. Roberts WP, Pierce JW. Deposition in Upper Patuxent Estuary, Maryland, 1968–1969. *Estuarine Coastal Shelf Sci.* 1976;4(3):267–280.

74. Schillinger JE, Gannon JJ. Bacterial adsorption and suspended particles in urban stormwater. *J Water Pollut Control Fed.* 1985;57:384–389.

75. Lerner DN. Identifying and quantifying urban recharge: a review. *Hydrogeology J.* 2002;10:143–152.

76. Lindesy G, Roberts L, Page W. Inspection and maintenance of infiltration facilities. *J Soil Water Conservation.* 1992;47:481–486.

77. Rajani B, McDonald S, Felio G. *Water Mains Break Data on Different Pipe Materials for 1992 and 1993.* Ottawa, Ontario: Nation Research Council of Canada Report; 1995. Client Report CR-7019.1.

78. Schreiber ME, Simo JA, Freiberg PG. Stratigraphic and geochemical controls on naturally occurring arsenic in groundwater, eastern Wisconsin, USA. *Hydrogeology J.* 2000;8:161–176.

79. *Drinking Water Infrastructure Needs Survey: Second Report to Congress.* Washington, DC: US Environmental Protection Agency; 2001. Report EPA-816-R-01-004.

80. *Clean Water Needs Survey Report to Congress, 1996: Assessment of Needs for Publicly Owned Wastewater Treatment Facilities, Correction of Combined Sewer Overflows and Management of Stormwater and Nonpoint Source Pollution in the United States.* Washington, DC: US Environmental Protection Agency; 1997. Report EPA-832-R-97-003.

81. Hunt WF. Stormwater BMP cost–effectiveness relationships for North Carolina. In: *Proceedings of Watershed 2002: Connecting You to a Higher Level of Expertise.* [CD-ROM] Alexandria, Va: Water Environment Federation; 2002.

82. *The Clean Water and Drinking Water Infrastructure Gap Analysis.* Washington, DC: US Environmental Protection Agency; 2002. Report EPA-816-R-02-020.

83. Schueler TR. Microbes and urban watersheds: concentrations, sources, and pathways. In: Schueler TR, Holland HK, eds. *The Practice of Watershed Protection.* Ellicott City, Md: Center for Watershed Protection; 2000:68–78.

84. *Costs and Benefits of Drinking Water Treatment.* Washington, DC: US Environmental Protection Agency; 1984. Report EPA-600-J-84-371.

85. *An Evaluation: Milwaukee Metropolitan Sewerage District.* Madison, Wis: Legislative Audit Bureau; 2002. Report 02-12.

86. Tufford DL, McKellar HN, Hussey JR. In-stream nonpoint source nutrient prediction with land-use proximity and seasonality. *J Environ Qual.* 1998;27: 100–111.

87. Brabec E, Schulte S, Richards PL. Impervious surfaces and water quality: a review of current literature and its implications for watershed planning. *J Plann Lit.* 2002;16:499–514.

88. *Draft Generic Environmental Impact Statement for the Draft Watershed Regulations for the Protection From Contamination, Degradation and Pollution of the New York City Water Supply and Its Sources.* Corona, NY: New York City Department of Environmental Protection; 1993.

89. Paden C, Shen A. New York City water under pressure. *Inside DEP.* 1995;1(1):1–8.

90. Planning Overlay, 33 Columbus City Codes, ch. 3372, §701–10 (2003).

91. Zheng PQ, Baetz BW. GIS-based analysis of development options from a hydrology perspective. *J Urban Plann Dev.* 1999;125:164–170.

92. Schueler TR. Comparative pollutant removal capability of stormwater treatment practices. In: Schueler TR, Holland HK, eds. *The Practice of Watershed Protection.* Ellicott City, Md: Center for Watershed Protection; 2000:31–36.

93. Yamada K, Funaki T, Honda S, Sugihara M. Study of diffuse source pollution management for land use and drainage system planning. *Water Sci Technol.* 2001;44:203–208.

94. Kronaveter L, Shamir U, Kessler A. Water-sensitive urban planning: modeling on-site infiltration. *J Water Resources Plann Manage.* 2001;127:78–88.

95. Kaufman MM, Wurtz M. Hydraulic and economic benefits of downspout diversion. *J Am Water Resources Assoc.* 1997;33:491–497.

Conventional Development Versus Managed Growth: The Costs of Sprawl

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Objectives. We examined the effects of sprawl, or conventional development, versus managed (or "smart") growth on land and infrastructure consumption as well as on real estate development and public service costs in the United States.

Methods. Mathematical impact models were used to produce US estimates of differences in resources consumed according to each growth scenario over the period 2000–2025.

Results. Sprawl produces a 21% increase in amount of undeveloped land converted to developed land (2.4 million acres) and approximately a 10% increase in local road lane-miles (188 300). Furthermore, sprawl causes about 10% more annual public service (fiscal) deficits ($4.2 billion) and 8% higher housing occupancy costs ($13 000 per dwelling unit).

Conclusions. Managed growth can save significant amounts of human and natural resources with limited effects on traditional development procedures. (*Am J Public Health.* 2003;93:1534–1540)

Land conversion involves the use of previously undeveloped land to accommodate development. Infrastructure includes the capital improvements necessitated by growth encompassing both roads and water/sewer facilities. Real estate development costs typically are considered on a cost-per-unit basis for a variety of types of residential and nonresidential units (e.g., single-family detached and attached homes, retail and office space). In terms of public service fiscal effects, development is directed toward areas of excess service capacity, as opposed to locations that would have to expand their public services and infrastructure. Thus, fiscal impacts involve long-term savings in operating costs in locations where development is currently taking place as opposed to locations where it could take place.[1–13]

The research summarized here contrasted 2 alternative development futures for the United States. One alternative is current development trends—labeled conventional development, or sprawl—extended into the future. Development of this type typically includes subdivision-style residential development and strip nonresidential development. The focus is on noncontiguous land development, including residential development in the form of 0.33- to 1.0-acre lots and nonresidential strip development involving floor-to-area ratios of 0.20 or less.[3] Such land development patterns would continue earlier trends of consumption of agricultural and sensitive environmental land, significant road/pavement construction, and high amounts of water and sewer infrastructure provision. Conventional development has been reported as contributing to both high real estate development costs for new development and negative fiscal effects on host public service jurisdictions.[2]

However, sprawl development also has benefits. For example, people have access to less expensive, single-family homes on large lots situated away from urban centers and a greater opportunity for participation in governance owing to the high number of small jurisdictions found in these peripheral areas. In addition, public service costs are lower in such areas as a result of the reduced need for a deep public service base.[4–13]

In the analyses described here these benefits were taken into account (i.e., both single-family purchase costs and public service expenditures are lower in areas away from urban centers), although increased participation in governance was not measured. However, managed growth remains more cost-efficient in the various cost comparisons undertaken. This observation is true in the first case because a greater array of housing is offered in areas close to urban centers, resulting in overall housing costs being lower in these areas in spite of lower peripheral single-family housing costs. The observation is true in the second case because tax rates in urban center areas are higher, generating even more revenues than are compensated for through reduced expenditures on a more limited array of services in areas farther out. In other words, the analyses described here encompassed and even validated the supposed benefits of sprawl, but managed growth, in spite of sprawl's benefits, remains more advantageous.

The second alternative is a more compact form of growth. Managed or "smart" growth seeks to contain most new growth around existing urban centers and to limit development in peripheral rural and sensitive environmental areas. It further seeks to reduce road construction and water/sewer infrastructure provision through higher-density development and, in some cases, mixed-use development. This goal is accomplished through increasing the share and density of development in areas closer to existing development and decreasing the share and density of development in the outer, more rural and undeveloped sections of a metropolitan area.

The research discussed here also involved a recognition that there are disadvantages associated with managed growth in the resource areas under investigation, including (1) increased housing costs owing to the land development limitations posed by managed growth, (2) extra governmental costs stemming from the administrative requirements of imposing a growth management regimen, and (3) the thwarting or driving away of development potential because of an overcontrolled real estate market. Again, these disadvantages were taken into account in the analyses.

All future development was accommodated within the assumptions of the present analysis—no development was denied—and real es-

tate development costs were found to be lower under managed growth. Thus, even after price increases in areas where development would be limited were accounted for, overall real estate development prices would be lower. Furthermore, encouraging development in areas where government is established decreases the costs of servicing this development. The excess capacity of public services found in these locations allows public services to be extended without the hiring of new personnel.

Finally, development incentives in the form of increased density were included in the managed growth scenario. These incentives provide an impetus for developers to build in areas closer to existing development. Reduced competition between developers building farther out ensures that many of those buying houses will continue to go there. These 2 benefits support the claims of equal development in a metropolitan area under each scenario. Development is not driven away.

Before examining the benefits of managed growth versus conventional development, it is necessary to ask, "Why is conventional development, with its resource consumption excesses, so popular?" The answer involves 3 considerations: market, policy, and personal. From a *market* perspective, as long as society is willing to provide adequate public services at a great distance from where these services currently exist at less than full cost to the recipient, single-family housing on large lots will be less expensive at greater distances from the center of a metropolitan area. To the degree that this development form continues to be desired, people will purchase in these locations. As this question relates to *policy,* if mortgage interest costs and real estate taxes continue to be tax deductible, and gasoline prices are maintained at low levels because the provision and upkeep of roads are not adequately represented in this tax, there will be a continued quest for unrestrained development in the United States.

Finally, from a *personal* perspective, if public safety is enhanced in peripheral locations and property taxes are lower because the social safety net need not be cast as wide, again the quest for peripheral development will continue. Market, policy, and personal choices support conventional development or sprawl because resources are relatively plentiful and no one is advocating for society's needs. Individual maximization is not societal maximization, and in the short run individual maximization involves bearable negative societal costs. However, these societal costs will increase as resources become scarce, and a different public mood will result.

METHODS

Models Used to Measure Resource Differences

The present analysis sought to determine 25-year (2000–2025) growth projections under the alternatives of conventional development and managed growth. The models used in the analysis create growth simulations and their effects on the basis of empirical relationships. Most of these are simple mathematical relationships that have been assembled through knowledge about how growth affects required resource supplies. These relationships are explained in more detail within each resource category.

The models begin with 2 identical projections of population and employment levels for a given US economic area made by Woods & Poole Economics Inc, a commercial vendor whose projection accuracy rates have been shown to be equivalent to those of the US census. Under alternative scenarios, different growth projections are made for different counties (the geographic unit of analysis in this study): rural and undeveloped counties are expected to experience more growth under conventional development, and urban and suburban counties are expected to experience more growth under managed growth. These projections are subjected to a housing model that changes them to different types of residential and nonresidential space and ultimately to land conversion, infrastructure, real estate development, and fiscal impact models that project land, road, and water/sewer infrastructure demands and housing/public service costs.

The resource requirements for nationwide growth over 25 years are large; thus, differences in resource consumption caused by alternative growth patterns are also large. Numbers are presented as they appear in terms of their mathematical extensions. As a result, they are both large and detailed. The accuracy rate that surrounds these numbers is generally about 10%. Projections of effects are not rounded; one can verify the mathematical extensions produced by the impact of each development scenario.

The County as the Geographic Unit of Analysis

Although the county is not a perfectly satisfactory geographic unit owing to size variations and the impossibility of controlling for intracounty development differences, the county used in this study to identify and analyze locations of residential and nonresidential development. The county was selected because (1) it is the smallest consistent noneducational unit of US government for which a large number of the demographic variables required for this analysis are consistently available; (2) a reasonable number of subdivisions of the United States as a whole are represented within this designation (approximately 3100 individual subjurisdictions); (3) projections of major demographic variables are available at this level; and (4) the problems of rapid growth and the economic and political incentives needed to redirect this growth increasingly require responses from governments of geographic areas that are larger than municipalities yet more accountable than regions with limited governance powers.

The limitations of using the county as a basic unit of analysis relate to size. We compensated for size differences by using county subunits (urbanized areas) to divide counties into smaller and different parts. Thus, even though the county is the basic unit of analysis, in about 1000 of the 3100 counties, subunits in the form of urbanized areas exist and are used as a centralized development area to redirect within-county growth. Intracounty growth is targeted toward urbanized areas and away from rural areas in the same way that intercounty growth is targeted to suburban and urban counties and away from rural and undeveloped counties. Thus, although the county is the focus of most projections, these projections actually incorporate subcounty areas in instances in which these areas were found to exist.

Any plausible redirection in growth from 1 area to another must account for existing eco-

nomic interrelationships among counties.[1] In other words, if households and jobs are to be directed elsewhere to control sprawl, those locations must fall within the commuting patterns that link households and jobs in a given area. The economic area aggregation developed by the Bureau of Economic Analysis fulfills this requirement. The economic area is one of the few data aggregations that merges metropolitan and nonmetropolitan locations into an economically related geographic area. It can be viewed as similar to an extended metropolitan area.

Within a given economic area, counties are classified according to their existing levels of development. The 6 land use development classifications are urban center, urban, suburban, rural center, rural, and undeveloped. These classifications, which are based on gross population density (population divided by surface area), identify a county as more or less developed relative to the other counties of its region and are an important consideration in determining where populations are to be redirected under the controlled growth scenario.[2] The gross density thresholds for the classifications vary according to state gross density groupings, which in turn differ by region of the country; for example, an urban location in New Jersey would have a gross density 10 times that of an urban location in Wyoming.

Defining Sprawl Generically and Empirically in US Counties

One of the most difficult tasks of this research was, in fact, to identify and characterize the development of sprawl. These difficulties are compounded if an attempt is made to define sprawl empirically. Sprawl is low-density, leapfrog development characterized by strip form along major thoroughfares and tributaries at the periphery of a metropolitan area. In other words, sprawl is significant residential or nonresidential development in a relatively pristine setting. In nearly every instance, this development is low density, it has leapt over other development to become established in an outlying area, and its very location indicates that it is unbounded. This definition of sprawl is well documented in the planning literature.[4–13] The definition of sprawl used in the present analysis was based on rapid and significant residential or nonresidential growth, or both, in rural and undeveloped counties. Numerous analyses of statistical population growth rates have defined the upper growth quartile as an indicator of significant growth or at least as separating significant and average growth. Here the upper quartile within an economic area was used to define significant growth.

All analyses of growth must contain both a relative and an absolute dimension. If absolute growth is taking place in a rural or undeveloped location at a multiple of the level of normal growth (in the present case, 160% of the national average absolute level), the location is defined as "sprawling," regardless of its relative rate of growth within the overall economic area. Therefore, sprawl is taking place in nonurban locations (rural and undeveloped counties)[1] if either of the following sets of criteria are met: (1) the county's growth rate is in the upper quartile of the economic area's annual county household and employment growth rates, the county's growth rate exceeds the national average annual absolute growth rate, and the county's absolute level of growth exceeds 40% of the national average annual absolute growth, or (2) the county's absolute level of growth exceeds 160% of the national average annual absolute growth. Given this definition of when and where sprawl takes place, sprawl will occur in 742 of 3091 counties during the 25-year projection period (2000–2025), or 24% of all counties in the United States. In addition, although sprawl development may be present in a significant sense in only 24% of counties, it will affect about 13.1 million of the 23.5 million new households projected for the period 2000 to 2025.

The Alternative Growth Scenario: Managed Growth

Managed growth is defined as limiting a significant share of development to already-developed counties or to areas as close to already-developed locations as possible. This limiting process takes place in 2 ways. The first method limits the amount of growth taking place in the outer counties of an economic area by redirecting it to inner counties. This is accomplished by establishing an urban growth boundary around the developed (urban and suburban) counties and allowing only a portion of the growth to occur in the less developed (rural and undeveloped) counties (intercounty sprawl control).

A second method of limiting sprawl curtails the outward movement of growth in a single county (intracounty sprawl control). This is accomplished by establishing an urban service area in a county and containing most of the growth within that area. A boundary is established around the existing concentration of growth (the urbanized area), and the remainder of the county is "protected" from significant development owing to the unavailability of adequate public services. These 2 methods of limiting sprawl combine to form the managed growth scenario. Over the 25-year projection period 2000 to 2025, the United States will grow under either scenario by 23.5 million households and 49 million jobs.

Table 1 summarizes redirections of households and jobs under the controlled growth scenario. Overall, 11% of new households and 6% of new jobs are directed away from counties that are sprawling (rural and developing counties experiencing significant residential or nonresidential growth). These percentages may seem relatively low, but they represent 2.6 million households and 3.1 million jobs. Redirection allows reductions in sprawl in a significant number of counties while basically maintaining market-driven preferences in terms of locations of households (see Table 1).[1]

RESULTS AND DISCUSSION

Land Conversion

Given projections under the conventional development scenario, over the next 25 years, the United States will convert 18.8 million acres of land to build 26.5 million new housing units and 26.5 billion square feet of new nonresidential space. Land will be converted at a rate of approximately 0.6 acres per residential unit and 0.2 acres per 1000 square feet of nonresidential space.

Land conversion requirements were determined by translating household and employment projections into demands for residential and nonresidential land. The model uses different housing types, development locations, and densities for conventional (sprawl) development and managed growth to calculate the

TABLE 1—Managed Growth: Household and Employment Redirection Summary, by Region, United States, 2000–2025

	Northeast	South	Midwest	West	Total
Households					
Projected growth (thousands)	1 476	10 664	3 450	7 865	23 454
Redirected growth (thousands)	2 102	1 138	298	915	2 561
Redirected growth, %	14.2	10.7	8.6	11.6	10.9
Percentage of US total	8.2	44.5	11.6	35.7	100.0
Jobs					
Projected growth (thousands)	6 049	19 022	10 457	13 890	49 418
Redirected growth (thousands)	422	915	462	1 338	3 137
Redirected growth, %	7.0	4.8	4.4	9.6	6.3
Percentage of US total	13.5	29.2	14.7	42.6	100.0

Note. Data were derived from the Center for Urban Policy Research, Rutgers University.

TABLE 2—Projected Land Savings Under the Managed Growth Scenario: Intercounty and Intracounty Redirections of Growth, by Region, United States, 2000–2025

Region	Total Savings (acres)	Intercounty Savings (acres), No. (%)	Intracounty Savings (acres), No. (%)
Northeast	282 853	172 276 (60.8)	110 985 (39.2)
Midwest	439 446	199 308 (45.4)	240 134 (54.6)
South	2 139 017	1 249 296 (58.4)	889 721 (41.6)
West	1 140 915	786 809 (69.0)	354 107 (31.0)
Total	4 002 231	2 407 688 (60.1)	1 594 947 (39.9)

Note. Data were derived from the Center for Urban Policy Research, Rutgers University.

total amount of land converted under each development alternative.[2,4–18] The process also accounts for both vacancy and additional land development requirements (e.g., roads/utilities, open spaces) that consume extra land. The model determines land conversion numbers by multiplying the prevailing density in each location by the number of development units destined for that location.

More than one fifth of this land conversion (21.3%) could be avoided through simple managed growth techniques without compromising types or location of growth or altering housing markets. About 2.4 million acres are projected to be saved by employing the equivalent of an urban growth boundary in economic areas to direct growth away from rural and undeveloped counties to more highly developed urban and suburban counties (Table 2). An additional 1.6 million acres are projected to be saved through the use of within-county urban service areas to direct development away from undeveloped to developed areas.

Water and Sewer Infrastructure

Water and sewer infrastructure demand calculations involve mathematical relationships between the number of units produced by type and their service through water and sewer laterals. Multifamily units are served by fewer laterals and require fewer outdoor sprinklers and less water use than single-family units. To the degree that types of units vary according to development scenario, so too do water/sewer demand and lateral use.

During the period 2000 to 2025, under conventional development, the United States is projected to expend just under $190 billion in providing necessary water and sewer infrastructure to primarily single-family detached subdivisions and associated single-use nonresidential developments (Table 3). Water and sewer systems will have to be expanded to accommodate the more than 18 billion gallons of additional water and sewer capacity needed. These delivery and collection systems under traditional development will require in excess of 45 million laterals (or equivalents) to service new residential and nonresidential structures. Much of this projected infrastructure requirement and its attending costs can be avoided through the more-compact growth patterns resulting from a managed growth regimen.[2,4–13,18,19]

With both intercounty and intracounty managed growth measures in place, more than 150 million gallons of water and sewer demand per day are projected to be saved without residential or nonresidential users being deprived of this fundamental utility. No

TABLE 3—Projected Water and Sewer Infrastructure Under Conventional Development and Managed Growth Scenarios, by Region: United States, 2000–2025

	Total Water and Sewer Demand, gal/d (Millions)			Total Water and Sewer Laterals (Thousands)			Total Infrastructure Costs, $ (Millions)		
Region	Conventional Development	Managed Growth	Demand Savings	Conventional Development	Managed Growth	Lateral Savings	Conventional Development	Managed Growth	Cost Savings
Northeast	1 451	1 444	7	3 406	3 068	338	16 015	14 751	1 264
Midwest	2 935	2 915	21	7 110	6 604	505	30 393	28 839	1 556
South	7 942	7 870	72	21 243	19 116	2 126	84 573	79 026	5 547
West	5 794	5 737	56	14 108	12 456	1 652	58 786	54 544	4 242
Total	18 121	17 965	156	45 867	41 245	4 621	189 767	177 160	12 609

Note. Data were derived from the Center for Urban Policy Research, Rutgers University.

domestic water use is curtailed; instead, buildings are situated in greater mass, and lawn sprinkling becomes less necessary or more efficient. The new development pattern, with more single-family attached and multifamily units, also allows for a less extensive delivery and collection system (street mains), resulting in lower tap-in fees. This reduced delivery system is determined by the mix of development and units served per water/sewer lateral in one location versus another. The combined cost savings of lower tap-in fees and 4.6 million fewer laterals project to an infrastructure savings of $12.6 billion, or 6.6%, over the observation period (Table 3).

Local Road Infrastructure

The demand for additional lane-mile local road capacity is related to population distribution and density. The present model relates road density to population density on the basis of within-county historical incidence figures. Projected population density in 2025 and the derived relationship between lane-mile density and population density were used to establish an ideal lane-mile level for each area of a given county. The model then predicts the need for new road construction by comparing ideal lane-mile levels and existing levels found in a county. This comparison is made for each alternative, and a road cost per lane mile is applied to estimate future road costs. The model does not project the costs associated with land acquisition, bridge upkeep, or repair or upkeep of roads.[2,4–13,19,20]

Under conventional development, the United States is projected to spend more than $927 billion during the period 2000 to 2025 to provide necessary road infrastructure, amounting to an additional 2 million lane-miles of local roads (Table 4). Under managed growth, 1.9 million new lane-miles are projected, amounting to $817 billion in local road costs.

Overall, a savings of 188 300 lane-miles and $110 billion could be achieved via managed growth patterns, which equates to a savings of 9.2% in terms of local lane-miles and 11.8% in terms of local road costs. Why are the savings not greater? Under either scenario, some development takes place in the outer and near-outer reaches of metropolitan areas, and local roads must be built. Even in the close-in areas where growth is directed under the managed growth scenario, local roads must often be widened by a lane in one or both directions to accommodate development, resulting in additional lane-miles.

Local Public Service Costs

Fiscal impact models measure the revenues versus costs of development by tallying property tax, nontax, and intergovernmental revenues and pairing them against the per capita, per pupil, and per worker costs associated with development. Though development usually does not pay for itself (i.e., costs exceed revenues), costs are lower in areas close to urban centers owing to economies of scale, and revenues from new development are higher as a result of the price differential relative to existing units. Under conventional development in peripheral areas, the nation is projected to expend $143.2 billion annually for public services during the period 2000 to 2025 and will collect annual revenues in the amount of $99.4 billion, resulting in an annual fiscal impact deficit of $43.8 billion by 2025 (Table 5).[2,4–13,21]

Under managed growth, emphasizing development locations closer to urban centers, the nation is projected to expend $139.2 billion annually in local public service costs, a decrease of $4 billion (Table 5). Such a decrease in costs is possible because, under managed growth, more development will take place in already-developed areas where public services may be more expensive but the demand for such services can be absorbed more readily owing to the excess service capacity found there. This $4 billion annual decrease can be paired against a similar aggregate annual revenue amount of approximately $99.5 billion. Thus, in 2025, projections indicate a positive fiscal impact of $4.2 billion (9.7%) annually under the managed growth versus the traditional development scenario. Thus, more-compact development or managed growth reduces the fiscal deficits traditionally associated with development.

Sprawl and Real Estate Development Costs

Real estate costs in a particular location reflect the costs of accommodations. If there is only single-family development, costs tend to be higher. If there are multiple types of development, costs are often lower because there is better pairing of space with household size needs. Real estate development models monitor the number of households of various sizes being established in different locations and the array of housing choices found in those locations.

The average residential housing cost in the United States is projected to decrease from $167 038 to $154 035 (in constant 2000 dollars) under the managed growth scenario, lowering the average housing cost nationwide for new housing occupants under conventional development by $13 003, or 7.8% (Table 6). This decrease is largely the result of a proportionately greater mix of housing units and their costs in locations close to urban centers versus the mix found farther out. Ideally, the purchase prices paid by individual home buyers will reflect these savings.[2,4–13,22]

TABLE 4—Projected Local Road Infrastructure Under Conventional Development and Managed Growth Scenarios, by Region: United States, 2000–2025

	Total Lane-Miles Required			Total Road Costs, $ (Billions)		
Region	Conventional Development	Managed Growth	Savings	Conventional Development	Managed Growth	Savings
Northeast	288 059	281 251	6 809	135.77	129.57	6.20
Midwest	4 164	266 614	17 550	130.76	122.15	8.61
South	885 944	806 955	78 989	376.99	338.07	38.92
West	586 011	501 055	84 957	283.49	227.52	55.98
Total	2 044 179	1 855 874	188 305	927.01	817.31	109.70

Note. Data were derived from the Center for Urban Policy Research, Rutgers University. Alaska is not included in the West region.

TABLE 5—Projected Fiscal Impact Under Conventional Development and Managed Growth Scenarios, by Region: United States, 2000–2025

	Conventional Development Scenario, $ (Millions)			Managed Growth Scenario, $ (Millions)			Difference: Conventional Minus Managed, $ (Millions)
Region	Costs	Revenues	Impact	Costs	Revenues	Impact	
Northeast	9 329	11 170	1 841	9 252	12 928	3 676	1 835
Midwest	18 914	15 352	–3 562	18 340	16 339	–2 001	1 561
South	58 441	38 845	–19 532	57 655	39 062	–18 531	1 001
West	56 558	34 023	–22 535	53 942	31 215	–22 728	–192
Total	143 242	99 389	–43 788	139 190	99 544	–39 583	4 205

Note. Data were derived from the Center for Urban Policy Research, Rutgers University.

TABLE 6—Projected Property Development Costs per Unit Under Conventional Development and Managed Growth Scenarios, by Region: United States, 2000–2025

	Conventional Development Growth		Managed Growth		Residential Savings		Nonresidential Savings	
Region	Residential	Nonresidential	Residential	Nonresidential	Units	%	Units	%
Northeast	246 418	85 705	228 329	84 277	18 089	7.3	1 428	1.7
Midwest	150 377	73 643	140 907	72 789	9 470	6.3	854	1.2
South	140 118	71 945	128 381	71 033	11 737	8.4	912	1.3
West	196 747	77 695	181 793	77 119	14 954	7.6	576	0.7
Total	167 038	75 463	154 035	74 598	13 003	7.8	865	1.1

Note. Data were derived from the Center for Urban Policy Research, Rutgers University.

CONCLUSIONS

What is found after a significant effort to study sprawl and its effects? First, conventional development or sprawl is the dominant form of growth occurring in major metropolitan areas. Even in metropolitan areas where there is no net new growth, transferred growth (i.e., growth that shifts from one area to another) is of a sprawl type. Thus, in the United States as of 2000, there existed 3 basic conditions, and these conditions continue in many cases.

First, there are rural or undeveloped counties (approximately 2100) in which a small amount of growth, or no growth, is occurring. Growth is too inconsequential in these counties to be classified as sprawl, although its characteristics are clearly sprawl-like. Second, there are urban centers and urban or developed suburban counties (approximately 250) that are declining or growing slowly and, accordingly, are not sprawling. In these counties, growth is negative or marginal. Also included in this group are a few urban counties that are growing. However, most of the development occurring in these locations is not of the sprawl type. Finally, there are rural, undeveloped, or developing suburban counties (approximately 740) where nearly all growth is sprawl. In our effort to document the magnitude of sprawl and analyze its effects, we focused on this last group of counties.

There appear to be significant costs of sprawl growth, and some of these costs are measurable. Conventional development or sprawl is projected to consume land and various types of infrastructure to a level that managed growth will not. Conventional development also is projected to result in fewer positive fiscal effects (more costs and somewhat less revenue) than managed growth. Furthermore, conventional development does not come in a form that provides for significant amounts of attached or multifamily housing. Because a mix of housing types is often not provided, primarily single-family units on larger lots at the periphery of metropolitan areas are chosen, and lower priced urban housing markets are not. Overall, housing costs are projected to be greater under conventional development.[23]

However, it is possible to accommodate growth in another way: a more centrally focused development pattern requiring fewer resources. This is managed growth.[24] Managed growth allows all development that would have taken place under conventional development to occur but directs that development to locations where public services can be provided more efficiently. This scenario results in appreciable savings in a relatively short period of time. Resources need not be as aggressively consumed, yet the amount of residential and nonresidential development is not altered. That is the message of this research.

Conventional development produces costs in dollar outlays and in resources consumed, and these costs are deceptively bearable in the short run. The benefits of unrestricted freedom of choice in regard to neighborhoods and lower housing costs seem worth the cost. In fact, they probably are. However, many of these benefits can be achieved through managed growth with little loss of freedom of choice or housing value and with significant savings of artificial and natural resources.

What is the importance of these findings to the public health community? The basis of the land use system in the United States is "police power"; everyone gives up a small portion of their property rights without compensation for the overall advancement of local public health safety and welfare. Current land use regulations promote public health by ensuring that there is enough air and light in structures and that ingress and egress are unencumbered. A new generation of land use regulations would promote public health, safety, and welfare by reducing the amount of land consumed, and this in turn would reduce the public dollars required for roads and infrastructure.

Rebuilding cities through redirecting growth would produce more-homogeneous resident populations in cities and suburbs, and thus a significantly lower amount of public funding would be required for either special needs or augmented public services in these areas. Future land use regulations promoting public health, safety, and welfare will

move from a focus on lot, light, and air considerations to a focus on development patterns and whether they achieve resource conservation in regard to land consumption, infrastructure provision, housing occupancy costs, and public service costs.

How will the present findings be received by those who would seek to promote the extension of public health, safety, and welfare described here? There may be apprehension that savings would be relatively small in comparison with opting for a development future that would require reigning in of the ability to build anywhere. That is, the public savings may not be significant enough to make it attractive to opt for broad-based regulatory changes in land use patterns. Such a view is shortsighted, however, because this scenario, applied to all development taking place in the United States, would result in large human and natural resource savings that could never accrue if the government were to tax or charge citizens to achieve them. ■

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Contributors

R.W. Burchell conceptualized the study and had primary responsibility for writing the article. S. Mukherji contributed to the writing of the article and to analysis of data.

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References

1. Burchell RW. Economic and fiscal costs (and benefits) of sprawl. *Urban Lawyer.* 1997;29:159–181.

2. Burchell RW, Dolphin WR, Galley CC. *The Costs and Benefits of Alternative Growth Patterns: The Impact Assessment of the New Jersey State Plan.* New Brunswick, NJ: Center for Urban Policy Research, Rutgers University; 2000.

3. Burchell RW, Downs A, Seskin S, et al. *The Costs of Sprawl Revisited.* Washington, DC: National Academy Press; 1998.

4. Burchell RW, Lowenstein G, Dolphin WR, et al. *The Costs of Sprawl–2000.* Washington, DC: National Academy Press; 2000.

5. *Beyond Sprawl: New Patterns of Growth to Fit the New California.* San Francisco, Calif: Bank of America, California Resources Agency, Greenbelt Alliance, Low-Income Housing Fund; 1995.

6. Downs A. *New Visions for Metropolitan America.* Washington, DC: Brookings Institution; 1994.

7. Ewing R. Is Los Angeles–style sprawl desirable? *J Am Plann Assoc.* 1997;63:107–126.

8. Moe R, Wilkie C. *Changing Places: Rebuilding Community in the Age of Sprawl.* New York, NY: Henry Holt; 1997.

9. *Smart Growth: Building Better Places to Live, Work and Play.* Washington, DC: National Association of Home Builders; 1999.

10. *The 1999 NAHB Smart Growth Conference: Participant Workbook.* Washington, DC: National Association of Home Builders; 1999.

11. Nelson AC, Duncan J. *Growth Management Principles and Practice.* Chicago, Ill: Planners Press; 1995.

12. Staley SR. *The Sprawling of America: In Defense of the Dynamic City.* Los Angeles, Calif: Reason Public Policy Institute; 1999. Policy study 251.

13. *Community Development: Extent of Federal Influence on "Urban Sprawl" Is Unclear.* Washington, DC: US General Accounting Office; 1999.

14. US Dept of Commerce, Bureau of the Census. Selected census data: population and housing counts: 2000. Available at: http://www.census.gov/population/www/cens2000/respop.html. Accessed June 25, 2003.

15. *CEDDS: The Complete Economic and Demographic Data Source.* Vols 1–3. Washington, DC: Woods & Poole Economics; 1998.

16. Burchell RW, Listokin D, Dolphin WR. *Development Impact Assessment Handbook.* Washington, DC: Urban Land Institute; 1994.

17. Landis JD. Imagining land use futures: applying the California Urban Futures Model. *J Am Plann Assoc.* 1995;61:438–457.

18. Duncan J. *The Search for Efficient Urban Growth Patterns.* Tallahassee, Fla: Florida Dept of Community Affairs; 1989.

19. Souza P. *New Capital Costs of Sprawl–Martin County, Florida.* Gainesville, Fla: University of Florida; 1995.

20. Cervero R, Klosterman K. Travel demand and the 3 Ds: density, diversity and design. *Transportation Res Digest.* 1996;2:199–219.

21. *Marginal Cost Analysis of Growth Alternatives–King County, Washington.* Bethesda, Md: Tischeler & Associates; 1994.

22. Parsons G. The effect of coastal land use restrictions on housing prices: a repeat sale analysis. *J Environ Econ Manage.* February 1992:25–37.

23. Delucchi MA. Environmental externalities of motor vehicle use in the US. *J Transportation Econ Policy.* 2000;3:220–228.

24. *Getting to Smart Growth: 100 Policies for Implementation.* Washington, DC: Sustainable Communities Network; 2002.

Urban Sprawl as a Risk Factor in Motor Vehicle Occupant and Pedestrian Fatalities

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Objectives. We sought to determine the association between urban sprawl and traffic fatalities.

Methods. We created a sprawl index by applying principal components analysis to data for 448 US counties in the largest 101 metropolitan areas. Regression analysis was used to determine associations between the index and traffic fatalities.

Results. For every 1% increase in the index (i.e., more compact, less sprawl), all-mode traffic fatality rates fell by 1.49% ($P<.001$) and pedestrian fatality rates fell by 1.47% to 3.56%, after adjustment for pedestrian exposure ($P<.001$).

Conclusions. Urban sprawl was directly related to traffic fatalities and pedestrian fatalities. Subsequent studies should investigate relationships at a finer geographic scale and should strive to improve on the measure of exposure used to adjust pedestrian fatality rates. (*Am J Public Health.* 2003;93:1541–1545)

Motor vehicle traffic deaths remain the leading cause of death among Americans aged between 1 and 34 years. In 2001, traffic crashes accounted for about 38 000 deaths, of which an estimated 4700 were pedestrians.[1] Although only about 5% of all trips are made on foot,[2] pedestrian fatalities make up about 12% of all traffic deaths, making walking one of the most dangerous modes of travel.[3]

Urban sprawl is suspected to be a major contributing cause of automobile and pedestrian traffic fatalities, but data supporting this suspicion are sparse.[3–6] Although "sprawl" has been variously defined, we consider the term to apply to any environment characterized by the following: a population widely dispersed in low-density residential development; rigid separation of homes, shops, and workplaces; a lack of distinct, thriving activity centers, such as strong downtowns or suburban town centers; and a network of roads marked by very large block size and poor access from one place to another.[7] One research group recently found that the most dangerous places to walk were sprawling metropolitan areas in the South and West, especially Orlando, Tampa–St Petersburg–Clearwater, West Palm Beach–Boca Raton, Memphis, Miami–Ft Lauderdale, Jacksonville, Houston, Phoenix–Mesa, Dallas–Ft Worth, and Nashville.[3] However, because sprawl was not measured explicitly, the possible association between sprawl and traffic fatalities could not be tested.

Previous studies modeled pedestrian crashes along roadway segments. The number of pedestrian–motor vehicle collisions has been shown to vary directly with pedestrian volume and traffic volume.[4,5] Suburban and outlying intersections have been significantly overrepresented in pedestrian crashes compared with more urban areas, after control for exposure and other location factors. The hypothesis that suburban roadways are particularly dangerous for pedestrians deserves to be tested at the macrolevel for a greater diversity of settings.

We recently measured urban sprawl at the level of the metropolitan area, using the 4 sprawl indicators just described to create a sprawl index.[8] In this study, the sprawl index was strongly associated with the overall traffic fatality rate, as well as with an array of transportation outcomes (e.g., percentage of residents walking or taking transit to work, average vehicle ownership, vehicle miles traveled per capita) and environmental outcomes (e.g., ground-level ozone levels).

In another recent study, we measured urban sprawl at the county level, using fewer variables than were available at the metropolitan level, and related county sprawl to leisure time physical activity, obesity, and certain chronic health problems associated with physical inactivity and obesity.[9] After we controlled for individual covariates such as gender, age, race/ethnicity, and education, sprawl proved to be significantly related to leisure time walking, obesity, and hypertension but not to overall physical activity, diabetes, or coronary heart disease.

The current study is a cross between the earlier 2 studies. It related sprawl to traffic fatalities as in the first study but also measured sprawl at the county level as in the second study. Large metropolitan areas mostly include several counties, each with differing development patterns. The finer geographic scale in this study might be expected to increase the explanatory power of resulting sprawl measures relative to the earlier metropolitan-level traffic fatality study.

METHODS

The sample in this study consisted of 448 metropolitan counties or statistically equivalent entities (e.g., independent towns and cities) according to the 1990 census, the latest year for which metropolitan boundaries were defined at the time our study began. These counties made up the 101 most populous metropolitan statistical areas, consolidated metropolitan statistical areas, and New England county metropolitan areas in the United States. Nonmetropolitan counties and metropolitan counties in smaller metropolitan areas were excluded from the sample. More than 183 million Americans—nearly two thirds of the United States population—lived in these 448 counties in 2000.[10]

Although sprawl has the 4 characteristics noted earlier, only 2 have been measured at the county level—low residential density and poor street accessibility. A county-based sprawl index was constructed as the main independent variable. It was composed of 6 observed variables: 4 related to residential den-

sity and 2 related to street accessibility from 1 place to another. We used US Census data to derive 3 population density measures for each county: (1) gross population density (persons per square mile); (2) percentage of the county population living at low suburban densities—specifically, densities between 101 and 1499 persons per square mile, corresponding to less than 1 housing unit per acre; and (3) percentage of the county population living at moderate to high urban densities—specifically, more than 12 500 persons per square mile, corresponding to about 8 housing units per acre, the lower limit of density needed to support mass transit.[11] In deriving these county population density measures, we excluded census tracts with fewer than 100 inhabitants per square mile (corresponding to rural areas, desert tracts, and other undeveloped lands) located within the county, because we were interested in studying sprawl in developed areas. A fourth, independent net-density variable was derived from estimated urban land area for each county from the Natural Resources Inventory of the US Department of Agriculture.[12]

Data reflecting street accessibility for each county were obtained from US Census data, based on information concerning block size.[13] A census block is defined as a statistical area bounded on all sides by streets, roads, streams, railroad tracks, or geopolitical boundary lines, in most cases.[14] A traditional urban neighborhood is composed of intersecting roads that create a boundary around a block or neighborhood. These roads form a grid, with houses built on the 4 sides of the block, facing these roads.[15] Therefore, the length of each side of that block, and the block size, is relatively small. By contrast, a contemporary suburban neighborhood does not make connections between adjacent cul-de-sacs or loop roads. Instead, local streets connect with the road at the subdivision entrance, which is on 1 side of the block boundary. Thus, the length of a side of a block is quite large, and the block itself often encloses multiple subdivisions to form a superblock extending a half-mile or more on each side. Large block sizes translate to a relative paucity of street connections and alternate routes. For each county, we calculated, first, average block size and second, percentage of blocks with areas less than 0.01 square mile, the size of a typical traditional urban block bounded by sides just over 500 feet in length. Tracts with blocks larger than 1 square mile were excluded from these calculations, because these were likely to be in rural or other undeveloped areas.

We used principal components analysis (SPSS Release 11.01; SPSS Inc, Chicago, Ill) to extract the single component (factor) that best represented the degree of sprawl, as indicated by its capture of the largest amount of common variance of these 6 variables. Because this component captured the majority of the combined variance of these variables, no subsequent components were considered.

To derive a county sprawl index, we transformed the principal component, which had a mean of 0 and a standard deviation of 1, to a scale with a mean of 100 and a standard deviation of 25. This transformation produced a more familiar metric (like an IQ scale) and ensured that all values would be positive, thereby enhancing our ability to test nonlinear relationships.

We analyzed the relationship between sprawl and each of 3 dependent variables: the all-mode, county-level traffic fatality rate and 2 county-level traffic fatality rates specific to pedestrians. The all-mode fatality rate included fatal crashes involving private motor vehicles, buses, trains, taxis, bicycles, and pedestrians. We restricted the analysis to traffic fatalities rather than injuries (which greatly outnumber fatalities), because high-quality data at a county level were available only for fatalities. Traffic fatality rates per 100 000 population were computed by dividing frequency counts for 2000 obtained from the Fatality Analysis Reporting System[16] by population counts obtained from the 2000 US Census.[10]

Using these archival data, we conducted an ecological study of the relationship between traffic fatality rates and the sprawl index, using the county as the unit of analysis. Because preliminary analysis indicated that the traffic fatality rate was a nonlinear function of the sprawl index (data not shown), a log-log transformation was performed to yield a more linear relationship between these variables. This involved computing the natural logarithms of all variables in the equation. As an added advantage of this transformation, the resulting regression coefficients could be interpreted as *elasticities*—that is, as percentage changes in a dependent variable that accompany a 1% change in independent variables. Elasticities are a common way of summarizing relationships in urban planning literature. Estimated with a log-log regression, elasticities can be assumed to be constant for the range of values in the dataset. We controlled for 3 covariates that could potentially confound the relationship between the sprawl index and traffic fatality rate (average household size, percentage of the population of working age, and per capita income) with data obtained from the 2000 US Census.

We next investigated the relationship between the sprawl index and pedestrian fatalities, using pedestrian fatality counts from the Fatality Analysis Reporting System. Because pedestrian fatality rates depend on the amount of walking,[17–20] we adjusted for such exposure, using the only 2 measures of pedestrian activity found in a national archival dataset that included county-level information.[21] These 2 measures were the proportion of all work trips taken on foot and the proportion of work trips taken by public transportation, which generally entails walking to and from a public transit stop. The former measure of pedestrian activity was used to adjust the pedestrian fatality count for 1 type of exposure. The sum of the former and the latter measures was used to adjust the pedestrian fatality count for another type of exposure. Such adjustments are important, because more compact land use patterns would be expected to generate more trips by pedestrians (greater modal share) and therefore greater exposure to hazard.

A log-log transformation was again performed to obtain a more linear relationship between fatality rates and the sprawl index. Because 96 (21%) of the counties had no pedestrian fatalities in 2000, 2 analyses were conducted. First, counties with no pedestrian fatalities were dropped from the sample, the logarithm of 0 being undefined. Most excluded counties were small, either suburban or exurban, with little pedestrian activity. Second, all counties were included, but 1 fatality was added to the pedestrian fatality count for each county. Accounting for counties with 0 fatalities should minimize a bias toward the

TABLE 1—Variable Loadings on Sprawl Index for Study Counties

Variable	Loading
Census gross density	0.846
Suburban density (<1500 persons/mi^2)	–0.698
Urban density (>12 500 persons/mi^2)	0.846
Natural Resources Inventory net density	0.849
Average block size	–0.698
Proportion of blocks <0.01 mi^2	0.821
Eigenvalue	3.8
Percentage of variance explained	63.4%

finding that sprawling counties are more dangerous for pedestrians.

We also controlled for the 3 covariates mentioned in the Methods (average household size, percentage of the population of working age, and per capita income). Significance was assumed to exist at $P<.05$.

RESULTS

In the principal components analysis, each of the 6 observed variables proved to be strongly related to the theoretical construct of urban sprawl (Table 1). The first principal component was positively related to gross population density, net population density, percentage of the county population living at moderate to high urban density, and percentage of small blocks. It was negatively related to percentage of the population living at low suburban density and average block size. Hence, higher values corresponded to a lesser degree of sprawl, and lower values to a greater degree of sprawl.

The absolute value of each loading—that is, the correlation between each of the 6 observed variables and the principal component—exceeded 0.6. The principal component accounted for 63.4% of the total variance among the 6 component variables.

We ranked the US counties in the sample by their sprawl index. Table 2 indicates which counties had the highest and lowest sprawl index values. Figure 1 shows a scattergram of the natural logarithms of the all-mode traffic fatality rate versus the sprawl index for all 448 counties. The most compact counties (i.e., those with highest population density and street accessibility and, therefore, the highest index value) were located in the central parts of the nation's oldest and largest metropolitan areas. The least compact counties (most sprawling, lowest index value) were located in outlying parts of smaller metropolitan areas in the Southeast and Midwest. Counties with midrange values on the sprawl index were located in central areas of low density or small metropolitan areas or were located in the first ring of suburbs around the central cities.

TABLE 2—US Counties With Highest and Lowest Sprawl Index Values

	County	Metropolitan Area	Sprawl Index[a]	All-Mode Traffic Fatality Rate (per 100 000)
1	New York County, NY	New York	352.07	4.42
2	Kings County, NY	New York	263.65	4.46
3	Bronx County, NY	New York	250.72	4.20
4	Queens County, NY	New York	218.90	4.58
5	San Francisco County, Calif	San Francisco	209.27	6.31
6	Hudson County, NJ	Jersey City	190.06	5.91
7	Philadelphia County, Pa	Philadelphia	187.78	8.04
8	Suffolk County, Mass	Boston–Lawrence–Salem	179.37	4.49
9	Richmond County, NY	New York	162.89	5.63
10	Baltimore City, Md	Baltimore	162.76	7.68
439	Stokes County, NC	Greensboro–Winston-Salem–High Point	71.26	15.66
440	Miami County, Kans	Kansas City	71.03	38.80
441	Davie County, NC	Greensboro–Winston-Salem–High Point	70.99	25.84
442	Isanti County, Minn	Minneapolis–St Paul	70.12	12.78
443	Walton County, Ga	Atlanta	69.61	19.77
444	Yadkin County, NC	Greensboro–Winston-Salem–High Point	69.17	38.52
445	Goochland County, Va	Richmond–Petersburg	67.59	35.58
446	Fulton County, Ohio	Toledo	66.83	38.02
447	Clinton County, Mich	Lansing–East Lansing	66.63	16.99
448	Geauga County, Ohio	Cleveland	63.12	20.90

[a]Higher values of the index indicate more compact urban form; lower values indicate more sprawling urban form.

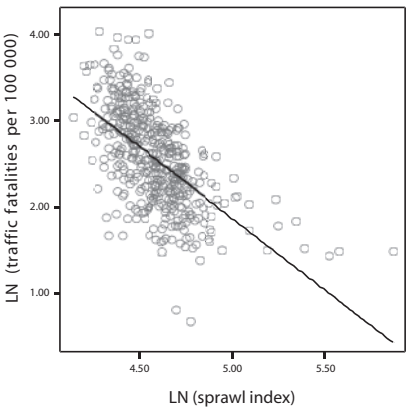

FIGURE 1—Logarithm of all-mode traffic fatality rate by logarithm of sprawl index: 448 counties, United States, 2000.

The sprawl index was negatively and significantly correlated with the all-mode traffic fatality rate, meaning that more compact counties had lower traffic fatality rates (Table 3). For every 1% increase in the index (e.g., increase in compactness), the traffic fatality rate decreased by 1.49%. The natural logarithms of the sprawl index, average household size, percentage of population of working age, and per capita income, taken together, accounted for 47% of the variance in the natural logarithm of the traffic fatality rate for all modes.

The sprawl index was also negatively and significantly correlated with the pedestrian fatality rate, after adjustment for exposure. This was true for both measures of exposure and for samples including all counties and only counties with 1 or more pedestrian fatalities.

TABLE 3—Regression Analysis of Association Between Sprawl Index and Fatality Rates

	Ln of All-Mode Traffic Fatality Rate (Coefficients and *t*-Statistics)	Ln of Pedestrian Fatality Rate (Coefficients and *t*-Statistics)			
		Adjusted for Walking Share of Commute Trips		Adjusted for Walking And Public Transportation Share of Commute Trips	
		Counties With Fatalities	All Counties	Counties With Fatalities	All Counties
Constant	15.5	12.0	14.0	29.5	31.8
Ln (sprawl index)	−1.49 (−14.7)***	−1.47 (−6.6)***	−2.04 (−10.7)***	−3.06 (−13.6)***	−3.56 (−18.3)***
Ln (average household size)	-0.22 (-0.8)	2.08 (3.3)**	2.10 (3.9)***	0.48 (0.8)	0.52 (0.9)
Ln (proportion of people of working age)	1.25 (2.3)*	1.27 (1.0)	1.76 (1.7)	0.97 (0.8)	1.12 (1.1)
Ln (per capita income)	−1.11 (−10.0)***	−0.80 (−3.1)**	−0.92 (−4.4)***	−1.61 (−6.2)***	−1.65 (−7.8)***
Adjusted R^2	0.47	0.18	0.29	0.43	0.52
Sample size	448	356	448	356	448

*$P<0.05$ level; **$P<0.01$ level; ***$P<0.001$.

For the 356 counties with pedestrian fatalities, every 1% increase in the sprawl index (increase in compactness) was associated with a 1.47% increase in the pedestrian fatality rate, after adjustment for the percentage of trips to work on foot, and a 3.06% increase in the pedestrian fatality rate, adjusted for the percentage of trips to work on foot or by transit ($P<.001$; Table 3). Sprawl was even more strongly associated with pedestrian fatalities when 1 fatality was added to the count for each county so that all counties could be included in the analysis (Table 3). Thus, regardless of which methodological approach was taken, more compact counties had lower pedestrian fatality rates, after adjustment for exposure and the 3 covariates.

DISCUSSION

Our study indicates that sprawl is a significant risk factor for traffic fatalities, especially for pedestrians. The recognition of this relationship is key; traffic safety can be added to the other health risks associated with urban sprawl—namely, physical inactivity and air and water pollution.[22–24]

Our study has certain strengths. The data used are of high quality and derive from independent datasets. They represent a very large sample of counties from across the nation, and the findings are significant, robust, and internally consistent. However, our study also has weaknesses. The study design is ecological in nature. It treats each county as a unit of homogeneous density and accessibility and assigns to it a single fatality rate, though large differences within borders are likely. In the future, whenever possible, analysis should involve finer levels of geography, such as census tracts. In certain circumstances, such as the study of behaviors antecedent to injury, analysis may need to extend down to the individual level.

Another limitation is our reduction of the complex phenomenon of urban sprawl to 2 dimensions, population density and street accessibility, as well as our use of only 6 variables to measure sprawl. We did this because county-level archival data were available for the entire nation for very few relevant variables. Future studies should seek or develop county-level, nationwide data for the other key characteristics of sprawl—namely, the rigid separation of homes, shops, and workplaces, as well as the lack of distinct, thriving activity centers, such as strong downtowns or suburban town centers.

We recognize that the fatality data studied are based on the location of a crash, whereas the population density and street accessibility data are based on place of residence, which may be different. To the extent that fatalities occurred during the morning or evening commute, a (reassuring) bias toward the null may exist. In other words, because most commuters who cross county borders live in lower-density bedroom communities and work in higher-density central areas, the traffic fatality rate in urban counties would be inflated relative to the population living there. Using these databases, we could not determine the extent to which such bias, if any, existed. One solution would be to study the relationship at the (multicounty) metropolitan area level, but such a focus would be at the expense of desired precision in the measurement of differences within metropolitan areas.

Finally, the journey-to-work data used to adjust the pedestrian fatality rates may not accurately reflect the overall amount of pedestrian activity occurring within a given county. For example, some people may not walk to work but may prefer this mode for shopping trips, school trips, and errands. Leisure time walking may be prevalent in sprawling places even if there are no shops, workplaces, or other destinations nearby and people are simply walking for exercise. Walk trips may be longer in sprawling places. We cannot determine whether a systematic bias exists among counties, such as might occur if suburban counties have sidewalk or trail systems that provide circulation within subdivisions or lead to nearby recreation sites, schools, and shopping destinations but not to distant workplaces. No travel mode data are currently available for all trip purposes for areas as small as counties.

Vehicle speed may make a large contribution to the difference in fatality rates observed between compact and sprawling counties.[25] Sprawling areas tend to have wide, long streets that encourage excessive speed. A pedestrian struck by a motor vehicle traveling at 40 mph has an 85% chance of being killed, compared with a 45% chance of death at 30 mph and a 5% chance at 20 mph.[26]

Thus, developing land in a more compact manner may reduce pedestrian deaths, provided that the street network is designed for lower-speed travel.

Additional studies are needed to confirm these findings and to extend our knowledge in key areas. A replication of results based on 1990 traffic fatality and urban form data would be useful. An exploration of the relationships among vehicle speed, fatality rates, and specific street design features common to urban sprawl (e.g., wide, long streets) would help guide countermeasures. Pedestrian injuries, which are 16 times more common than fatalities, should be studied to determine whether their relationship to sprawl is similar to that of pedestrian fatalities. At present, because no complete and reliable pedestrian injury data are available for small areas, the ability to study injuries requires new data-collection activities. Pedestrian fatalities should be studied for high-risk populations such as the elderly, children, and minorities. Perhaps most important, future research should work toward the development and use of more precise measures of pedestrian exposure to permit a better understanding of the relationship of urban sprawl to traffic risks. ■

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Contributors

R. Ewing conceived of the study, developed the study design, collected data, and conducted the analysis. R.A. Schieber and C.V. Zegeer prepared the manuscript.

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References

1. Hilton J, Shankar U. *2001 Motor Vehicle Traffic Crashes: Injury and Fatality Estimates, Early Assessment.* Washington, DC: US Dept of Transportation, HS 809–439; 2002.

2. Federal Highway Administration. *National Bicycling and Walking Study: Five Year Status Report by the US Department of Transportation, April 22, 1999.* Available at: http://www.fhwa.dot.gov/environment/bikeped/Study.htm. Accessed December 15, 2002.

3. Surface Transportation Policy Project (STPP). Mean Streets 2002. Available at: www.transact.org/PDFs/ms2002/MeanStreets2002.pdf. Accessed December 15, 2002.

4. Zegeer C, Stewart R, Huang H, Lagerwey P. Safety effects of marked vs unmarked crosswalks at uncontrolled locations: analysis of pedestrian crashes in 30 cities. *Transport Res Rec.* 2001;1773:56–68.

5. Zegeer C, Opiels K, Cynecki M. Effects of pedestrian signals and signal timing on pedestrian accidents. *Transport Res Rec.* 1982;847:62–72.

6. Lucy WH, Rabalais R. Traffic fatalities and homicides by strangers: danger of leaving home in cities, inner suburbs, and outer suburbs. Available at: http://arch.virginia.edu/exurbia/death-in-exurbia.pdf. Accessed December 15, 2002.

7. Ewing R. Is Los Angeles style sprawl desirable? *J Am Planning Assoc.* 1997;63(1):107–126.

8. Ewing R, Pendall R, Chen D. Measuring sprawl and its impact. Smart Growth America 2002. Available at: http://www.smartgrowthamerica.org/sprawlindex/MeasuringSprawl.pdf. Accessed December 15, 2002.

9. Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Urban form, physical activity and health. *Am J Health Promotion.* In press.

10. US Bureau of the Census. *Census 2000 Summary File 1, Census of Population and Housing.* Washington, DC: US Bureau of the Census; 2001.

11. Messenger T, Ewing R. Transit-oriented development in the sunbelt. *Transport Res Rec.* 1996;1552: 145–152

12. United States Department of Agriculture. *1997 National Resources Inventory* [machine-readable data on CD-ROM]. Revised data, Alpha release, March 2001.

13. US Bureau of the Census. *UA Census 2000 TIGER/LineR files* [machine-readable data files]. Washington, DC: US Dept of Commerce; 2002.

14. US Bureau of the Census. UA Census 2000 TIGER/LineR file technical documentation. Washington, DC: US Bureau of the Census; 2002.

15. Neuman T. *Geometric Design: Urban Intersections, The Traffic Safety Toolbox- A Primer on Traffic Safety.* Washington, DC: Institute of Transportation Engineers; 1999.

16. National Highway Traffic Safety Administration, Fatality Analysis Reporting System (FARS). Washington, DC: US Dept of Transportation. Available at: http://ftp.nhtsa.dot.gov/FARS. Accessed December 15, 2002.

17. Roberts I. Why have child pedestrian death rates fallen? *BMJ.* 1993;306:1737–1739.

18. Roberts I. What does a decline in child pedestrian injury rates mean? *Am J Public Health.* 1995;85: 268–269.

19. Roberts I, Keall MD, Frith WJ. Pedestrian exposure and the risk of child pedestrian injury. *J Paediatr Child Health.* 1994;30:220–223.

20. DiGuiseppi C, Roberts I, Li L, Allen D. Determinants of car travel on daily journeys to school: cross sectional survey of primary school children. *BMJ.* 1998;316:1426–1428.

21. US Bureau of the Census. Census 2000 Summary File 3 [machine-readable data files]. Washington, DC: US Bureau of the Census; 2002.

22. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002;117:201–217.

23. Jackson RJ, Kochtitzky C. *Creating a Healthy Environment: The Impact of the Built Environment on Public Health.* Washington, DC: Sprawl Watch Clearinghouse; 2001.

24. Roper WL, Kraft MK, Killingsworth RE, Mofson P, Starrett B. Health and smart growth: building health, promoting active communities. Funders' Network for Smart Growth and Livable Communities. Available at: http://www.fundersnetwork.org. Accessed December 15, 2002.

25. Surface Transportation Policy Project (STPP). Aggressive Driving: Where You Live Matters. Available at http://www.transact.org/report.asp. Accessed December 15, 2002.

26. UK Department of Transportation. Killing Speeds and Saving Lives. London, England: UK Dept of Transportation; 1987.

Social Capital and the Built Environment: The Importance of Walkable Neighborhoods

Kevin M. Leyden, PhD

Objectives. I sought to examine whether pedestrian-oriented, mixed-use neighborhoods encourage enhanced levels of social and community engagement (i.e., social capital).

Methods. The study investigated the relationship between neighborhood design and individual levels of social capital. Data were obtained from a household survey that measured the social capital of citizens living in neighborhoods that ranged from traditional, mixed-use, pedestrian-oriented designs to modern, car-dependent suburban subdivisions in Galway, Ireland.

Results. The analyses indicate that persons living in walkable, mixed-use neighborhoods have higher levels of social capital compared with those living in car-oriented suburbs. Respondents living in walkable neighborhoods were more likely to know their neighbors, participate politically, trust others, and be socially engaged.

Conclusions. Walkable, mixed-use neighborhood designs can encourage the development of social capital. (*Am J Public Health.* 2003;93:1546–1551)

A growing number of researchers agree that social networks and community involvement have positive health consequences. Persons who are socially engaged with others and actively involved in their communities tend to live longer and be healthier physically and mentally.[1–12]

> The more integrated we are with our community, the less likely we are to experience colds, heart attacks, strokes, cancer, depression, and premature death of all sorts. . . . Over the last 20 years more than a dozen large studies . . . have shown that *people who are socially disconnected are between 2 and 5 times more likely to die from all causes, compared with matched individuals who have close ties with family, friends, and the community.*[13(p326–327)]

Social and community ties are key components of a more encompassing concept, *social capital.* Social capital is defined as the social networks and interactions that inspire trust and reciprocity among citizens.[13] Individuals with high levels of social capital tend to be involved politically, to volunteer in their communities, and to get together more frequently with friends and neighbors. They are also more likely to trust or to think kindly of others.[13–15] Social capital has been found to be linked to more than just good health; empirical linkages have been found among social capital, the proper functioning of democracy, the prevention of crime, and enhanced economic development.[13]

An understanding of why some persons and some communities have more social capital than others is important to improving public health. Factors associated with the decline of social capital in recent decades include pressures of time and money on families, long commutes, television usage, and generational change.[13] Many of these factors appear to be related to suburbanization.[16,17]

This study examined whether the built environment (i.e., the way we design and build our communities and neighborhoods) affects the degree to which people are involved in their communities and with each other. The fundamental premise is that some neighborhood designs *enable or encourage* social ties or community connections, whereas others do not. Theoretically, the neighborhood designs (or types) most likely to promote social capital are those that are mixed use and pedestrian oriented. Such neighborhoods (usually labeled "traditional" or "complete" neighborhoods) are typically found in older cities and older rural towns.[18] These neighborhoods are walkable, enabling residents to perform daily activities (e.g., grocery shopping, going to the park, taking children to school) without the use of a car. Many of these neighborhoods have places of worship, a local tavern, a coffee shop, or restaurants within walking distance. Complete or traditional neighborhoods encourage walking; pedestrians are not forced to compete with cars along busy highways or to walk across expansive parking lots.

This traditional or complete neighborhood design can be contrasted with its modern suburban counterpart. Today's version of the neighborhood, the suburban subdivision, contains only houses. Daily needs are not met in the neighborhood or even in town; they are instead fulfilled at large megastores in malls or strip malls located along 4-lane connector roads that are typically clogged with traffic. If residents want to shop, worship, or go to a restaurant, pub, park, or library, they must travel by car. Many contemporary suburban subdivisions do not even have sidewalks: citizens must drive to find a place to exercise or to go for a walk.

Theoretically, pedestrian-oriented, mixed-use neighborhoods are expected to enhance social capital because they enable residents to interact. This interaction can be intentional or accidental. Spontaneous "bumping into" neighbors, brief (seemingly trivial) conversations, or just waving hello can help to encourage a sense of trust and a sense of connection between people and the places they live. These casual contacts can occur at neighborhood corner shops, at local parks, or on the sidewalk. To many residents, such contacts breed a sense of familiarity and predictability that most people find comforting. When summed over time, these individual occurrences have been theorized to be of great importance for fostering "a web of public respect and trust, and a resource in time of personal or neighborhood need."[19(p56)]

In contrast, most contemporary suburban subdivisions do little to enable social interaction. Social interaction is more likely to occur by invitation, not by chance encounter. Life is supposed to take place within the home or in

the backyard.[20] In many suburbs, privacy and the automobile are so highly valued that developers do not even bother to lay sidewalks. Corner stores, taverns, coffee shops, and sometimes schools and parks often are not found in the neighborhood, because zoning ordinances have rendered them illegal within residential areas. Most modern, car-dependent suburbs are not places designed to encourage social interaction.

This study examined the relationship between neighborhood design and social capital. The main hypothesis is that pedestrian-oriented, mixed-use neighborhoods are more likely to encourage social capital than are car-dependent, single-use neighborhoods.

METHODS

To examine the relationship between neighborhood design and social capital, a survey was conducted in and around the city of Galway, located in the Republic of Ireland. Galway's population was estimated at 65 457 in April 2001, with an additional 30 000 people living "in the immediate environs."[21] Galway is the fastest-growing city in Ireland and one of the fastest-growing cities in Europe. It was chosen for this analysis because it has a mix of neighborhood types ranging from the truly mixed-use, pedestrian-oriented variety (built centuries before the automobile) to the contemporary, American-style suburb. Moreover, Galway has no experience with the racism and "white flight" from the city centers that has historically affected American cities and that in many ways continues to distort decisions regarding where to live.

During April and May of 2001, 750 households in Galway and its suburbs were surveyed by mail. The cover letter asked that the survey be completed and returned by 1 adult member (aged 18 years or older) of each selected household. To sample from a variety of neighborhood types, 8 neighborhoods or suburban subdivisions were chosen. In 6 of these neighborhoods (or suburban subdivisions), a survey was delivered to each and every residence. In the other 2, a portion of the subdivision was chosen at random because of the subdivision's size. In this portion or part of the subdivision, all houses received a survey. A total of 279 surveys were returned, for an overall response rate of 37.2%. No follow-up surveys were mailed.

Neighborhood Categories

Galway's neighborhoods were subjectively categorized into 3 ideal types by the researcher before conducting the survey. The neighborhoods selected and surveyed include the following 3 types.

City Center/Near City Center Neighborhoods. The category of "city center/near city center" includes mixed-use, pedestrian-oriented neighborhoods where all daily needs and forms of entertainment are a short walk away. Residents living in these neighborhoods could walk to restaurants, pubs, parks, libraries, department stores, government buildings, post offices, butchers, banks, pharmacies, local schools, theatres, and places of worship without seriously competing with cars.

Older, Mixed-Use Suburbs. Galway has several older suburbs that incorporate some of the more positive aspects of both the traditional city center neighborhood and the quiet suburb. Renmore, for example, has many traditional neighborhood amenities, such as local schools, a few neighborhood corner shops, a centrally located bus line, a church, community center, and playing fields. However, it is much quieter and more predictable than Galway's city center neighborhoods, and the range of places one could access by foot is clearly more limited.

Modern, Automobile-Dependent Suburbs. Galway's recent economic boom has created a demand for new housing that has been met by creating new suburbs. These modern suburbs are car oriented; even local stores have a strip-mall feel about them. With parking lots positioned in front, they seem to suggest that driving is expected. Few places can be accessed by foot, and many of these suburbs do not have sidewalks or parks.

Key Independent Variable: Individual Assessments of Neighborhood Walkability

Categorization of Galway's various neighborhoods ensured that the individuals in the study's sample lived in a range of neighborhood types. In most of the following analysis, however, the assessment of neighborhood "walkability" was made by the respondents, not by the researcher. All survey respondents were asked to rate the degree to which their neighborhoods were pedestrian oriented and mixed use (Figure 1). This question was used to create a variable called "neighborhood walkability," which is an additive index of the 9 places listed in Figure 1. Each respondent was assigned a neighborhood walkability score that could range from 0 (cannot walk to any of the places mentioned) to 9 (can walk to all of them).

Additional independent variables in the multivariate models include controls found to correlate with various aspects of social capital in previous political science and sociological studies.[13,22–25] These measures included age, whether a respondent has children currently living at home ("child in home"), how much television a respondent watches ("watch TV"), whether and to what degree a respondent attends religious services, how long a respondent has lived in his or her current neighborhood ("years in the neighborhood"), education level, and the degree to which a respondent reports being committed to a political party ("party strength").

A lot of people are very dependent on a car these days to get where they want to go. If you or another family member wanted to which of the following could you walk to without too much trouble? *Tick all you could walk to without too much trouble.*

___1. A local corner shop/newsagent
___2. A church
___3. A park (or pitch)
___4. A local school
___5. A Community Center or Recreation Center
___6. A crèche (or child care facility)
___7. A Chemist (or pharmacy)
___8. A Pub
___9. The place that I work
___10. None of the above. It is hard to really go anywhere without a car.

FIGURE 1—Survey questions used to create the "neighborhood walkability" measure.

Dependent Variables: Measures of Social Capital

The survey conducted for this study measured 4 key aspects of social capital: how well residents knew their neighbors, their political participation, their trust or faith in other people, and their social engagement. These dependent variables were measured as described in the following paragraphs.

The variable "know neighbors" was measured with the following question: "Think about the neighborhood or area in which you live. In general, how well do you feel you know your neighbors? (1) Not at all, (2) Just a little, (3) Moderately well, (4) Extremely well."

Political participation was measured as an additive index. The Political Participation Index assessed whether respondents voted in the last general election, whether they had volunteered to work for a political party in the past 5 years, and whether they had contacted an elected official to express their views in the past 6 months. Each of these activities was scored as either 1 (yes) or 0 (no), and scores were added to create the index. Thus, for each respondent, the variable could range from 0 (no participation) to 3 (yes to all 3 items).

The Trust Index measured whether respondents felt that people could be trusted, whether they thought people were fair, and whether they thought most people try to be helpful. Scores on this index could also range from 0 (a complete absence of trust and faith in others) to 3 (respondent feels that people can be trusted, are fair, and are helpful).

Social participation was measured with 4 questions probing the degree to which respondents reported being engaged socially. The first question asked respondents to report how often they got together with friends: "rarely," "occasionally," or "a great deal." The next 3 questions asked respondents to specify the number of times (in the past 2 weeks) they had gone "out to a pub or restaurant with friends"; the number of times they had invited friends into their home "for company, tea, or a meal"; and the number of times they had gone to a friend's home "for company, tea, or a meal." Summing the responses on all 4 items for each respondent yielded an index score reflecting each respondent's degree of social engagement. The mean Social Index score was 7.04, and the standard deviation was 5.41.

Data Analysis

All statistical analyses were performed with Stata, version 7 (Stata Corp, College Station, Tex). The first part of the analysis sought to establish whether the "subjective" categorizations of neighborhood types established by the researcher before the surveys were distributed helped to illustrate some of the differences between walkable and more car-oriented neighborhoods. This was accomplished by examining whether the means of the various aspects of social capital differed statistically (using *t* tests) by neighborhood type.

The heart of the analysis used multivariate ordered logit models to examine the effect of the neighborhood walkability measure on the 4 dependent measures of social capital. Ordered logit was used because of the ordinal nature of the dependent variables. Although all of the dependent measures of social capital can be ranked, the distance between categories cannot be assumed to be equal (as in interval data). In the analysis that follows, the neighborhood walkability measure was scored in 2 ways. In the first set of regressions, neighborhood walkability for each respondent was scored from 0 to 9; in the second set, this variable was recoded to assess the odds of respondents' having high levels of social capital if they assessed their neighborhoods to be highly pedestrian oriented and mixed use (high scores of 7, 8, or 9 were coded as 1, whereas lower scores were coded as 0).

RESULTS

Table 1 illustrates some of the differences between more walkable, mixed-use neighborhoods and those that are car dependent. Shown in the table are the means and corresponding *P* values (based on the *t* tests) of measures related to social capital (note that preinvestigative categorizations of neighborhood types are used). All respondents living in mixed-use, pedestrian-oriented neighborhoods (city center/near city center plus older, mixed-use suburbs) were combined and compared with those living in modern suburbs. Interestingly, neighborhood walkability was statistically significant ($P<.0001$), indicating that respondents' self-assessments of their own neighborhoods coincided with the neighborhood categorizations established by the researcher before administration of the survey. Residents living in neighborhoods categorized as walkable by the researcher perceived their neighborhoods as being more walkable.

Table 1 provides examples of how attitudes and behaviors of residents living in pedestrian-oriented, mixed-use neighborhoods (whether located in older suburbs or in town) differ from those of residents living in car-dependent suburbs. Table 1 displays data demonstrating that in complete or traditional neighborhoods, residents walk more (or at least perceive their neighborhoods to be more walkable), feel more connected to (or part of) their community, are more likely to know their neighbors, are more likely to trust or have faith in other people, are more

TABLE 1—Pedestrian-Oriented, Mixed-Use Neighborhoods vs Modern, Automobile-Dependent Suburbs: Galway, Ireland, 2001

	Comparing Means Using *t* Test		
	Mixed-use, Walkable Neighborhood (n = 163), Mean	Car-Dependent Suburban Neighborhood (n = 109), Mean	*P* Value
Neighborhood walkability	7.35	4.72	.0001
Feel connected to or part of the community	2.94	2.39	.0001
Know neighbors?	2.67	2.22	.0001
Trust Index	2.32	2.09	.0329
Contacting elected officials	0.32	0.17	.0032
Can walk to work	0.51	0.19	.0001

TABLE 2—Multivariate Ordered Logit Models for Social Capital, by Independent Variable: Galway, Ireland, 2001

	Odds Ratio (95% Confidence Interval)			
Independent Variable	Know Neighbors (n = 256)	Political Participation Index (n = 258)	Trust Index (n = 258)	Social Index (n = 258)
Neighborhood walkability	1.28† (1.14, 1.44)	1.14** (1.02, 1.28)	1.15*** (1.04, 1.28)	1.20† (1.09, 1.32)
Age	1.06† (1.03, 1.08)	1.01 (.99, 1.04)	1.02 (0.99, 1.04)	0.95† (0.93, 0.97)
Child in home	2.80† (1.65, 4.75)	1.51 (0.90, 2.53)	1.17 (0.71, 1.91)	0.33† (0.21, 0.53)
Watch TV	0.085 (0.61, 1.17)	0.89 (0.64, 1.23)	0.87 (0.64, 1.18)	0.78* (0.59, 1.04)
Attend religious services	1.20** (1.01, 1.42)	1.14 (0.95, 1.36)	1.03 (0.88, 1.22)	0.97 (0.83, 1.13)
Years in neighborhood	1.03** (1.00,1.05)	1.02 (0.99, 1.04)	0.99 (0.97, 1.02)	0.98* (0.96, 1.00)
Education	0.72 (0.45, 1.17)	1.77** (1.10, 2.83)	0.87 (0.54, 1.39)	1.03 (0.68, 1.57)
Party strength	1.16 (0.88, 1.52)	1.98† (1.50, 2.62)	1.04 (0.80, 1.35)	1.22* (0.96, 1.54)
McKelvey and Zavoina R^2	.44	.19	.07	.26

*P = .10; **P = .05; ***P = .01; †P = .001; 2-tailed test.

likely to contact elected officials to express their concerns, and are more likely to walk to work.

Although suggestive, simple mean comparisons do not control for other factors that might also explain why residents in one neighborhood type demonstrate higher levels of social capital. A multivariate model is needed. Table 2 displays the results of the multivariate ordered logit models examining the impact of neighborhood walkability on various aspects of social capital, after control for other independent variables. The results are clear and consistent: the more places respondents report being able to walk to in their neighborhood, the higher their level of social capital. This relation suggests that walkable, mixed-use neighborhoods are better generators of social capital than are modern, car-dependent suburbs.

The odds ratios (ORs) reported in Table 2 were generated with ordered logit regression. It is important to note that neighborhood walkability scores ranged from 0 to 9 and that the odds ratios must be interpreted with this in mind. A 1-unit increase in neighborhood walkability score is linked with an increase of 1.28 (95% confidence level [CI] = 1.14, 1.44) in the odds that a resident knows his or her neighbors. Therefore, the more walkable a neighborhood (and the more places that can be walked to), the more likely a resident is to know his or her neighbors.

The neighborhood walkability measure was also statistically significant in the equations examining political participation and trust. The higher the neighborhood walkability rating assigned by respondents, the more likely they were to participate politically (OR = 1.14; 95% CI = 1.02, 1.28) and to have trust or faith in others (OR = 1.15; 95% CI = 1.04, 1.28).

The fourth measure of social capital was the Social Index, reflecting the degree to which a respondent reports being socially engaged. The model demonstrated that the more places respondents reported being able to walk to in their neighborhood, the more likely they were to be engaged with others socially (OR = 1.20; 95% CI = 1.09, 1.32). Interestingly, the model also indicated that respondents become less social as they grow older (OR = 0.95; 95% CI = 0.93, 0.97), that people with children living in the home are less social (OR = 0.33; 95% CI = 0.21, 0.53), and that watching TV limits one's social activities (OR = 0.78; 95% CI = 0.59, 1.04).

The neighborhood walkability measure had a statistically significant effect on all of the measures of social capital. No other predictor was consistently significant. Moreover, neighborhood walkability consistently held its own in comparison with the other predictors, often playing a more powerful role. Stata reports a standardized odds ratio (not shown here) based on standard deviational changes in the independent variable.[26] Neighborhood walkability was the most important predictor of the Trust Index, the second most important predictor for the Know Neighbors variable and the Social Index, and a close third for the Political Participation Index.

Table 3 explores the effects had by the most walkable (and most mixed-use) neighborhoods on social capital. Respondents who reported their neighborhoods as being highly walkable and mixed use (7, 8, or 9 on the original neighborhood walkability measure) were compared with those who rank their neighborhoods as less pedestrian oriented and less mixed use, after control for other factors. The results indicated that residents living in high-walkability neighborhoods (many in this category reported walking to work) were likely to score higher on all measures of social capital. The odds ratios ranged from 1.80 to 1.95, and all were statistically significant in the predicted direction.

TABLE 3—Multivariate Ordered Logit Models of Social Capital: Highly Walkable, Mixed-use Designs vs All Others: Galway, Ireland, 2001

	Odds Ratio (95% Confidence Interval)			
	Know Neighbors	Political Participation Index	Trust Index	Social Index
High level of neighborhood walkability or mixed-use design	1.88** (1.14, 3.11)	1.83* (1.10, 3.05)	1.79* (1.10, 2.92)	1.95** (1.25, 3.05)

Note. A high level of neighborhood walkability or mixed-use design was scored 1 if a respondent reported a 7, 8, or 9 on the neighborhood walkability measure and scored 0 otherwise. All other independent control variables were included in the analysis, as in Table 2.
*P = .05; **P = .01; 2-tailed test.

DISCUSSION

This study suggests that the way we design and build our communities and neighborhoods affects social capital and thus physical and mental health. The results indicate that residents living in walkable, mixed-use neighborhoods are more likely to know their neighbors, to participate politically, to trust others, and to be involved socially.

Unfortunately, America's built environment has been moving in a direction that is likely to have a negative effect on social capital. Over the last several decades, buying a home in a neighborhood that resembles the traditional, mixed-use, pedestrian-oriented model has become increasingly difficult. In fact, many Americans have no choice but to live in a modern, car-dependent suburb, because not enough viable, affordable traditional neighborhoods exist; their options are biased toward car-dependent suburban subdivisions, because such environments are what most developers build.[27]

The trend toward building car-dependent subdivisions is not just the fault of the developers. That American communities have become increasingly car oriented and less walkable is also the result of municipal zoning codes and other public policy changes that clearly promote transport by private vehicle, deemphasize public transport, and discourage (or even outlaw) the building of mixed-use, pedestrian-oriented neighborhoods.[18,28] Changing this trend will require political will and a shift in land-use and transportation priorities and policies.[29,30] Public consciousness must also change. Government policy has helped to change the public's view of smoking and of race and gender discrimination; it could help change our concept of the built environment by discouraging sprawl and encouraging the creation of new pedestrian-oriented towns and neighborhoods. Changes in government policy and tax law might also encourage the revitalization of existing traditional neighborhoods.

Of course, before we get to that point, we need to know more about how the built environment affects health and social capital. This study has several limitations. To what degree can the results of this study, which was based on a fairly small Irish city, be generalized? Selection bias also may have affected the results. Social people might be more likely to choose walkable neighborhoods, rather then walkable neighborhoods' encouraging sociability. The models presented in Tables 2 and 3 attempted to statistically control for this possibility by including measures of age and years in the neighborhood. However, the selection bias needs to be untangled; a much larger longitudinal study would be required to do so. In addition, much more must be learned about which architectural aspects of the built environment most affect health and social capital. This study used a measure that allowed respondents to rate the walkability of their own neighborhoods; more information is needed regarding how measures such as block size, density, street widths, and traffic speed affect the perceived walkability of a neighborhood[18–20] and social capital.

Finally, more data must be gathered regarding how the built environment affects health in general.[31] To what extent is our car-dependent, "drive-through" suburban culture discouraging physical activity,[32–34] thus encouraging obesity[35–39] and other associated health problems?[38,39] How does sprawl affect health over the life span? According to the Centers for Disease Control and Prevention, today's built environment is affecting how children travel to school. Instead of walking or biking to school, most children are now driven by bus or private vehicle; the main deterrents to walking or biking are long distances (55%) and traffic danger (40%).[40,41] One must wonder whether the short-sighted planning decisions that lead to so many young people being driven rather than walking will have long-term health consequences. How are the elderly affected? Does car-dependent sprawl contribute to the sort of social isolation that negatively affects the health of seniors? The consequences of not walking and of not interacting with others may have consequences far more negative, for persons of all ages, than we ever imagined. ■

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References

1. Kaplan GA. Social contacts and ischaemic heart disease. *Ann Clin Res.* 1988;20:131–136.

2. House JS, Landis KR, Umberson D. Social relationships and health. *Science.* 1988;241:540–545.

3. Berkman LF. The role of social relations in health promotion. *Psychosomatic Med.* 1995;57:245–254.

4. Berkman LF, Syme SL. Social networks, host resistance and mortality: a nine year follow-up of Alameda County residents. *Am J Epidemiol.* 1979;109: 186–204.

5. House JS, Robbins C, Metzner HL. The association of social relationships and activities with mortality: prospective evidence from the Tecumseh Community Health Study. *Am J Epidemiol.* 1982;116:123–140.

6. Seeman TE, Kaplan GA, Knudsen L, Cohen R, Guralnik J. Social networks ties and mortality among the elderly in the Alameda County Study. *Am J Epidemiol.* 1987;126:714–723.

7. Kawachi I, Kennedy BP, Glass R. Social capital and self-rated health: a contextual analysis. *Am J Public Health.* 1999;89:1187–1193.

8. Kawachi I. Social capital and community effects on population and individual health. *Ann N Y Acad Sci.* 1999;896:120–130.

9. Yen IH, Kaplan GA. Neighborhood social environment and risk of death: multilevel evidence from the Alameda County Study. *Am J Epidemiol.* 1999;149: 898–907.

10. Berkman LF, Glass T, Brissette I, Seeman TE. From social integration to health: Durkheim in the new millennium. *Soc Sci Med.* 2000;51:843–857.

11. Kawachi I, Berkman LF. Social ties and mental health. *J Urban Health.* 2001;78:458–67

12. Brummett BH, Barefoot JC, Siegler IC, et al. Characteristics of socially isolated patients with coronary artery disease who are at elevated risk for mortality. *Psychosom Med.* 2001;63:267–272.

13. Putnam RD. *Bowling Alone: The Collapse and Revival of American Community.* New York, NY: Simon & Schuster; 2000.

14. Coleman JS. *Foundations of Social Theory.* Cambridge, Mass: Harvard University Press; 1990.

15. Fukuyama F. *Trust: Social Virtues and the Creation of Prosperity.* New York, NY: Free Press; 1995.

16. Oliver JE. *Democracy in Suburbia.* Princeton, NJ: Princeton University Press; 2001.

17. Freeman, L. The effects of sprawl on neighborhood social ties: an explanatory analysis. *J Am Plann Assoc.* 2001;67:69–77.

18. Duany A, Plater-Zyberk E, Speck J. *Suburban Nation: The Rise of Sprawl and the Decline of the American Dream.* New York, NY: North Point Press; 2000.

19. Jacobs J. *The Death and Life of Great American Cities.* New York, NY: Random House; 1961.

20. Lofland LH. *The Public Realm: Exploring the City's Quintessential Social Territory.* Hawthorne, NY: Aldine De Gruyter; 1998.

21. Galway City Council Web site. Available at: http://www.galwaycity.ie. Accessed August 2002.

22. Kasarda JD, Janowitz M. Community attachment in mass society. *Am Sociol Rev.* 1974;39:328–339

23. Rosenstone SJ, Hansen JM. *Mobilization, Participation, and Democracy in America.* New York, NY: Macmillan Publishing Co; 1993.

24. Sampson RJ. Local friendship ties and community attachment in mass society: a multilevel systemic model. *Am Sociol Rev.* 1988;53:766–779.

25. Verba S, Schlozman KL, Brady HE. *Voice and Equality: Civic Voluntarism in American Politics.* Cambridge, Mass: Harvard University Press; 1995.

26. Long JS, Freese J. *Regression Models for Categorical Dependent Variables Using STATA.* College Station, Tex: Stata Press; 2001.

27. The Urban Land Institute Web site. Available at: http://www.uli.org. Accessed April 2003.

28. Calthorpe P, Fulton W. *The Regional City.* Washington, DC: Island Press; 2001.

29. Newman P, Kenworthy J. *Sustainability and Cities.* Washington, DC: Island Press; 1999.

30. Cervero R. *The Transit Metropolis.* Washington, DC: Island Press; 1998.

31. Frumkin H. Urban sprawl and public health. *Public Health Rep.* 2002;117(3):201–217.

32. Mokdad AH, Bowman BA, Ford ES, et al. The continuing epidemics of obesity and diabetes in the United States. *JAMA.* 2001;286:1195–1200.

33. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults. *JAMA.* 2002;288:1723–1727.

34. Ogden CL, Flegal KM, Carroll MD, Johnson CL. Prevalence and trends in overweight among US children and adolescents, 1999–2000. *JAMA.* 2002;288:1728–1732.

35. Manson JE, Greenland P, LaCroix AZ, et al. Walking compared with vigorous exercise for the prevention of cardiovascular events in women. *N Engl J Med.* 2002;347:716–725.

36. Lee IM, Rexrode KM, Cook NR, Manson JE, Buring JE. Physical activity and coronary heart disease in women: is "no gain, no pain" passe? *JAMA.* 2001;285:1447–1454.

37. Paillard T, Lafont C, Costes-Salon MC, Dupui P, Riviere D, Vellas B. Cholesterol reduction and increased cardiovascular fitness following a 12 weeks brisk walking. *J Nutr Health Aging.* 2002;6(2):138–140.

38. Feskanich D, Willett W, Colditz G. Walking and leisure-time activity and risk of hip fracture in postmenopausal women. *JAMA.* 2002;288:2300–2306.

39. Kraus WE, Houmard JA, Duscha BD, et al. Effects of the amount and intensity of exercise on plasma lipoproteins. *N Engl J Med.* 2002;347:1483–1492.

40. Centers for Disease Control and Prevention. Barriers to children walking and biking to school—United States, 1999. *JAMA.* 2002;288:1343–1344.

41. US Dept of Transportation. Available at: http://www.nhtsa.dot.gov/people/injury/pedbimot/ped/saferouteshtml/toc.html. Accessed April 2003.

Neighborhood-Based Differences in Physical Activity: An Environment Scale Evaluation

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Objectives. This study evaluated a neighborhood environment survey and compared the physical activity and weight status of the residents in 2 neighborhoods.

Methods. On 2 occasions, 107 adults from neighborhoods with differing "walkability" were selected to complete a survey on their neighborhood environment. Physical activity was assessed by self-report and by accelerometer; height and weight were assessed by self-report.

Results. Neighborhood environment characteristics had moderate to high test–retest reliabilities. Residents of high-walkability neighborhoods reported higher residential density, land use mix, street connectivity, aesthetics, and safety. They had more than 70 more minutes of physical activity and had lower obesity prevalence (adjusted for individual demographics) than did residents of low-walkability neighborhoods.

Conclusions. The reliability and validity of self-reported neighborhood environment subscales were supported. Neighborhood environment was associated with physical activity and overweight prevalence. (*Am J Public Health.* 2003;93:1552–1558)

We have observed growing disappointment among researchers with the inability of individually oriented models to adequately explain the high population prevalence of physical inactivity.[1] The inability of individually focused interventions to create long-term change or population shifts in physical activity also is disappointing.[2,3] However, interest in the potential of multilevel ecological models to facilitate a better understanding of physical-environment effects on behavior has increased.[4,5] The small but growing health literature on this subject documents relations between numerous environmental variables and physical activity but provides few definitive explanations.[6,7] Further investigation of the environmental correlates of physical activity is needed and could lead to improved interventions.

The negative effects of low-density, automobile-dependent, segregated-use patterns of land and transport system development are attracting public health attention.[8] Transportation studies indicate that people living in "traditional" neighborhoods—characterized by higher residential density, a mixture of land uses (residential and commercial), and gridlike street patterns with short block lengths—engage in more walking and cycling trips for transport than do people living in sprawling neighborhoods.[9] Transportation research currently provides the best evidence that environmental factors can contribute to low levels of lifestyle physical activity,[10] because many Americans live in environments that can be characterized as low in "walkability."[11]

From a physical activity and health perspective, transportation studies have numerous shortcomings: the contribution of community design to overall physical activity is unknown, only a small number of environmental variables have been studied, and reliable and valid measures of environmental variables are not available.[9] Our study builds on the strengths of transportation research to fill important knowledge gaps. We evaluated self-report measures of neighborhood environment variables hypothesized to be important contributors to physical activity.[7,12,13] On the basis of transportation research and to a model of environmental influences on physical activity,[9,14] self-report measures of neighborhood environmental constructs were developed and assessed for reliability and construct validity. We also compared physical activity and weight status among adult residents living in neighborhoods characterized as having high or low "walkability," which is defined by residential density, mixed land use, and street connectivity.[9]

METHODS

Participants

We recruited residents from 2 neighborhoods defined as nonadjacent 1990 census tracts in San Diego, California. The high-walkability neighborhood had a mixture of single-family and multiple-family residences, which is consistent with higher residential density, whereas the low-walkability neighborhood had predominantly single-family homes. The high-walkability neighborhood had a concentration of nonresidential land uses (restaurants, grocery or convenience stores, and other small retail stores) along the main corridor of the neighborhood, whereas the low-walkability neighborhood was mostly residential and had only a small commercial area on the neighborhood periphery. The high-walkability neighborhood had a mostly gridlike street pattern, with short block lengths and few cul-de-sacs, which is indicative of greater street connectivity. The low-walkability neighborhood had longer block lengths, a mixture of gridlike and curvilinear street patterns, and more cul-de-sacs. According to the 1990 census, the neighborhoods had similar census tract—level median income (high-walkability neighborhood, $40 170; low-walkability neighborhood, $46 647) and median resident age (high-walkability neighborhood, 39.9 years; low-walkability neighborhood, 36.5 years).

Potential participants were identified through a Haines & Company, Inc (North Canton, Ohio) reverse directory that sorts households alphabetically by street address rather than by last name. For streets that extended beyond census tract boundaries, only those residents with street addresses within the identified census tract were eligible to participate. Residences with telephone numbers were randomly selected from within the neighborhoods.

The residents were mailed an introductory letter and a study consent form. They were then contacted by telephone, with up to 6 calls attempted, to assess study interest and eligibility. Eligibility criteria included (1) still living within the identified neighborhoods, (2) being 18 to 65 years old, (3) not having a disability that precluded walking, and (4) being able to complete written surveys in English. Sample size requirements were based on estimated differences (observed in transportation research) in walking rates between high- and low-walkability neighborhoods.[9] After we adopted a more conservative effect size (effective size statistic [d]= .65) than that derived from the transportation literature (d=1.0),[9] we determined that 46 participants from each neighborhood were needed to detect a moderate to large effect size with more than 80% power.[15] Recruitment continued until approximately 50 individuals from each neighborhood had completed the survey and had provided objective physical-activity data.

Contact by mail and telephone was attempted with 600 individuals in the high-walkability neighborhood and with 707 individuals in the low-walkability neighborhood; 30.5% and 26.3%, respectively, could not be reached by telephone. Among the telephone contacts in the high- and low-walkability neighborhoods, respectively, 41.2% and 53.6% refused participation, 39.1% and 31.5% were not eligible, and 19.7% and 15.0% agreed to participate. Age was the primary reason for ineligibility in both neighborhoods. Among the individuals who agreed to participate, 81.7% (n=67) in the high-walkability neighborhood and 82.0% (n=64) in the low-walkability neighborhood returned signed consent forms.

Nine participants dropped out after consenting to participate (n=4 in the high-walkability neighborhood, n=5 in the low-walkability neighborhood), and 12 participants were unable to complete the survey either because they did not wear the activity monitor long enough or because the activity monitor malfunctioned (n=7 in the high-walkability neighborhood, n=5 in the low-walkability neighborhood; no significant demographic differences between those who did and did not complete the survey). One hundred ten participants provided objective physical activity data and completed surveys. Among these participants, 3 (n=2 in the high-walkability neighborhood, n=1 in the low-walkability neighborhood) were removed from analyses because they were outliers on objective physical activity measures (>3 standard deviations above the mean), which resulted in a sample of 107 participants (n=54 in the high-walkability neighborhood, n=53 in the low-walkability neighborhood). Results of tests of statistical differences between the neighborhoods were the same regardless of whether the outliers were included in analyses. Participant demographic characteristics are shown in Table 1.

TABLE 1—Participant Demographics by Neighborhood

	High-Walkability Neighborhood (n=54)	Low-Walkability Neighborhood (n=53)	*P* Value
Female, %	51.9	54.7	NS
Age, mean (SD), y	44.9 (11.6)	50.8 (10.7)	.008
Ethnicity, %			
White	79.6	83.0	NS
Hispanic/Latino	13.0	5.7	NS
Asian/Pacific Islander	3.7	5.7	NS
Black	0	1.9	NS
Multiple ethnicities	3.7	3.7	NS
Completed college/university, %	63.0	41.5	.026

Note. NS= not significant, *P*>.05.

Procedures

Participant contact was solely by telephone and mail. When research staff received a signed written consent form, the participant was mailed a uniaxial accelerometer/activity monitor (CSA Model 7164; Computer Sciences Applications Inc, Shalimar, Fla). Participants were instructed to attach the activity monitor to an adjustable belt and to wear it firmly around the waist, positioned just above the right hip. The activity monitor was to be worn for 7 consecutive days during waking hours when the participant was not engaged in water-related activities such as swimming and showering.

Four to 5 days after sending the activity monitors, research staff sent participants a survey and encouraged them to complete them and mail them back with the activity monitors. Approximately 1 week after receiving the completed first survey, research staff sent a second survey. When all measures were completed, participants were compensated $20.

Measures

Activity Monitor. The CSA activity monitor provided an objective measure of physical activity. It collected minute-by-minute activity counts that were collapsed into minutes spent across the 7 days in intensity levels of light, moderate, hard, and very hard activity based on cutpoints derived from previous research.[16] Hard-activity and very-hard-activity minutes were combined to create an estimate of vigorous physical activity. CSA-derived information correlates highly with heart rate and with other movement and energy-expenditure estimates.[17] It provides a valid estimate of physical activity even in nonlaboratory settings,[18] particularly in the case of moderate-intensity physical activities such as walking.[19]

Surveys. A new survey was developed to assess neighborhood environment characteristics hypothesized to be related to physical activity. The first 2 authors and a community group composed of transportation, environmental protection, and urban planning professionals created the survey, which was based on empirical literature from transportation planning and urban planning.[9] It assessed several environmental characteristics: (1) residential density; (2) proximity to, and ease of access to, nonresidential land uses, such as restaurants

and retail stores (land use mix–diversity and land use mix–access); (3) street connectivity; (4) walking/cycling facilities, such as sidewalks and pedestrian/bike trails; (5) aesthetics; (6) traffic safety; and (7) crime safety. With the exception of the residential density and land use mix–diversity subscales, items were scaled from 1 (strongly disagree) to 4 (strongly agree), with higher scores indicating a more favorable value of the environmental characteristic. Residential density items asked about the frequency of various types of neighborhood residences, from single-family detached homes to 13-story or higher apartments/condominiums, with a response range of 1 (none) to 5 (all). Residential density items were weighted relative to the average density of single-family detached residences (e.g., 7- to 12-story apartments and condominiums were considered to be 50 times more person-dense than single-family residences), and weighted values were summed to create a residential density subscale score. Land use mix–diversity was assessed by the walking proximity from home to various types of stores and facilities, with responses ranging from 1- to 5-minute walking distance (coded as 5) to ≥30-minute walking distance (coded as 1). Higher scores on land use mix–diversity indicated closer average proximity. With the exception of the residential density subscale, all subscale scores were calculated as the mean across the subscale items. Sample items from the Neighborhood Environment Walkability Scale (NEWS) are shown in Table 2.

In addition to the NEWS, the first survey contained a validated and reliable self-report walking assessment that asked about the number of minutes spent during the past week walking to or from work or school, during breaks or lunch at work or school, as part of errands done outside the household, for exercise, and to/from transit stops.[20] Total self-reported walking was the sum of time across walking purposes. Leisure time physical activity was assessed with the Godin–Shephard Leisure Time Exercise Questionnaire.[21] The first survey also included demographic questions, including questions about age, gender, ethnicity, height, weight, and level of education. Body mass index (BMI) was calculated as kg/m^2; overweight was defined as BMI >25. Level of education was dichotomized as completing college and higher or not completing college and lower. The second survey contained only the perceived-environment subscales that were part of the first survey.

TABLE 2—Subscales and Sample Items From the Neighborhood Environment Walkability Scale

Subscale	Sample Items
Residential density	How common are detached single-family residences in your immediate neighborhood?
	How common are apartments or condos 1–3 stories in your immediate neighborhood?
Land use mix-diversity	About how long would it take to get from your home to the *nearest* businesses or facilities if you *walked* to them?
	• Convenience/small grocery store
	• Post office
	• Video store
	• Non-fast food restaurant
Land use mix-access	I can do most of my shopping at local stores.
	Parking is difficult in local shopping areas.
Street connectivity	The streets in my neighborhood do not have many, or any, cul-de-sacs.
	The distance between intersections in my neighborhood is usually short.
Walking/cycling facilities	The sidewalks in my neighborhood are well maintained.
	There is a grass/dirt strip that separates the streets from sidewalks in my neighborhood.
Aesthetics	There are many attractive natural sights in my neighborhood (such as landscaping, views).
	There are attractive buildings/homes in my neighborhood.
Pedestrian/automobile traffic safety	The speed of traffic on most nearby streets is usually slow (30 mph or less).
	There are crosswalks and pedestrian signals to help walkers cross busy streets in my neighborhood.
Crime safety	There is a high crime rate in my neighborhood.
	My neighborhood streets are well lit at night.

Note: The complete Neighborhood Environment Walkability Scale (NEWS) and scoring procedures are available at http://www.drjamessallis.sdsu.edu/NEWS.pdf and http://www.drjamessallis.sdsu.edu/NEWSscoring.pdf, respectively.

Data Analytic Plan

The data were evaluated for normality and for potential outliers. Three individuals with extremely high accelerometer values were eliminated from the analyses. In addition, 1 individual with an extreme score on self-reported walking for errands (>6 standard deviations above the mean) was removed from the self-reported walking analyses but was retained in other analyses. Self-reported walking scores had high positive kurtosis and positive skewness; thus, logarithmic transformations were used in analyses, with median values presented as measures of central tendency. Accelerometer and perceived-environment data were neither highly skewed nor kurtotic; these data were not transformed. Mean values are presented.

One-way model single-measure intraclass correlations were used to evaluate the test–retest reliability of the NEWS subscales. One participant did not return the second survey and was not included in the reliability analyses. Differences between residents of the 2 neighborhoods on demographics, perceived neighborhood environment (from Survey 1), physical activity, and BMI were examined with 1-way analysis of variance (ANOVA) for continuous variables and with χ^2 tests for dichotomous variables. In addition to our examining the amount of self-reported walking time by purpose, dichotomized values of walking by purpose (e.g., walking for exercise vs not walking for exercise) were analyzed for neighborhood differences. We used analysis of covariance (ANCOVA) tests for continuous outcomes and logistic regression for dichotomous outcomes in analyzing neighborhood differences when adjusting for resident age

TABLE 3—Test–Retest Reliability[a] and Mean (SD) Subscale Scores From the Neighborhood Environment Walkability Scale

Neighborhood Environment Factor or Subscale	Test–Retest Reliability (n = 106)	Mean (SD) Subscale Score: High-Walkability Neighborhood (n = 54)	Mean (SD) Subscale Score: Low-Walkability Neighborhood (n = 53)
Residential density	.63	203.2 (19.2)*	194.4 (21.6)
Land use mix–diversity	.78	3.5 (0.6)*	2.8 (0.7)
Land use mix–access	.79	3.2 (0.3)*	2.8 (0.5)
Street connectivity	.63	3.2 (0.5)*	2.9 (0.5)
Walking/cycling facilities	.58	3.0 (0.3)	3.2 (0.4)**
Aesthetics	.79	3.0 (0.5)*	2.8 (0.5)
Pedestrian/traffic safety	.77	3.1 (0.5)*	2.7 (0.5)
Crime safety	.80	3.1 (0.4)	3.1 (0.5)

Note. Subscale scores ranged from 1 to 4 (with the exceptions of land use mix–diversity [possible range: 1–5] and residential density [possible weighted score range: 177–473]), with higher scores indicating a more favorable value of the environmental characteristic

[a]Intraclass correlation, *R*.

*high walkability > low walkability, $P < .03$; **low walkability > high walkability, $P = .003$.

and education level. Analyses were conducted in SPSS 10.0 (SPSS Inc, Chicago, Ill), and all tests were 2-tailed.

RESULTS

Validity and Test–Retest Reliability of the NEWS

Table 3 shows that residents in the high-walkability neighborhood perceived their neighborhoods as having higher residential density, land use mix–diversity, land use mix–access, street connectivity, aesthetics, and pedestrian/automobile traffic safety than did residents of the low-walkability neighborhood (all F statistic [F] $F_{1,105} > 9.69$, $P < .003$). However, low-walkability neighborhood residents reported having more facilities for walking/cycling ($F_{1,105} = 9.07$, $P = .003$). There were no differences between neighborhoods in perceived crime safety ($F_{1,105} = 0.002$, $P = .97$). Perceived-environment findings were not altered substantially by the inclusion of participant age and education level as covariates.

The median amount of time between participants' returning the first and second surveys was 15 days. Intraclass correlations for the test–retest reliability of the NEWS subscales were all ≥.58, and the majority of test–retest values were ≥.75 (all $F_{1,105} > 3.78$, $P < .001$].

Physical Activity and Weight Status Differences

Table 4 shows that residents in the high-walkability neighborhood engaged in approximately 52 more minutes of moderate-intensity physical activity during the past 7 days than did residents of the low-walkability neighborhood ($F_{1,105} = 6.02$, $P = .016$). This difference was the primary contributor to greater overall objectively measured physical activity among high- versus low-walkability neighborhood residents ($F_{1,105} = 6.80$, $P = .010$). These significant neighborhood differences were maintained after adjustment for participant age and education level. In contrast, high- and low-walkability neighborhood residents did not significantly differ in amount of objectively measured vigorous-intensity physical activity.

High-walkability neighborhood residents reported spending more time walking for errands and during breaks at work or school than low-walkability neighborhood residents, but these differences did not remain statistically significant after adjustment for age and education. The difference among neighborhoods in total self-reported walking approached statistical significance ($F_{1,104} = 2.88$, $P = .093$), but the covariates attenuated this difference. Percentage of residents walking for errands was higher in the high-walkability neighborhood than in the low-walkability neighborhood (85.2% vs 59.6%; $\chi^2[1] = 8.72$, $P = .003$), as was the percentage of residents walking during breaks at work or school (50% vs 25%, $\chi^2[1] = 7.05$, $P = .008$). However, after participant age and education level were entered into the logistic model, only walking for errands had a significant neighborhood term ($\beta = 1.04$, SE = .50, $P = .01$). No significant differences by neighborhood type were observed in self-reported frequency of engaging in mild, moderate, or strenuous physical activity during the past week either before or after adjustment for participant age and education level. The comparison of BMI between high- and low-walkability neighborhood approached statistical significance, with residents of low-walkability neighborhoods having a higher average BMI than residents of high-walkability neighborhoods (27.4 vs 25.3, $F_{1,106} = 3.89$, $P = .051$). This difference was attenuated somewhat by the inclusion of participant age and education level covariates (27.3 vs 25.4, $F_{1,103} = 2.81$, $P = .097$). A greater percentage of residents from the low-walkability neighborhood than from the high-walkability neighborhood met criteria for overweight (60.4% vs 35.2%; $\chi^2[1] = 6.81$, $P = .009$). Neighborhood walkability remained significant in a logistic regression model of overweight prevalence after we entered participant age and education level ($\beta = 0.86$, SE = .42, $P = .043$].

DISCUSSION

Our findings strongly supported the test–retest reliability and validity of a new self-report measure of neighborhood environment characteristics hypothesized to be related to lifestyle physical activity, particularly walking for transport. Most of the NEWS subscales had test–retest reliability above .75, which is a high level of consistency. Scales that assessed residential density, walking/cycling facilities, and street connectivity had lower, but still acceptable, reliability. Item difficulty could explain the lower reliability of the street connectivity subscale, because some judgments, such as street block length, were difficult. There also was little variability in some walking/cycling facilities and residential density items, including items that asked whether sidewalks (high frequency in both neighborhoods) and apart-

TABLE 4—Walking and Physical Activity by Neighborhood

Outcome	Unadjusted		Adjusted for Participant Age and Education Level	
	High-Walkability Neighborhood (n = 54)	Low-Walkability Neighborhood (n = 53)[a]	High-Walkability Neighborhood (n = 54)	Low-Walkability Neighborhood (n = 53)
CSA-measured physical activity (mean [SD] total minutes during past 7 days)				
Moderate-intensity physical activity	188.7 (116.5)*	136.9 (101.2)	194.8**	130.7
Vigorous-intensity physical activity	18.1 (44.6)	6.7 (18.9)	15.7	9.1
Total physical activity	206.8 (138.1)*	143.6 (110.8)	210.5**	139.9
Self-reported walking for various purposes (median total minutes during past 7 days)				
To or from work or school	0.0	0.0	NA	NA
To or from bus/transit stop	0.0	0.0	NA	NA
For errands outside home	30.0*	15.0	NA	NA
During breaks at work or school	2.5**	0.0	NA	NA
For exercise	30.0	20.0	NA	NA
Total walking	137.5	65.0	NA	NA
Godin–Shephard Leisure Time Exercise Questionnaire (mean [SD] times per week)				
Mild	3.0 (3.3)	2.6 (3.0)	3.1	2.5
Moderate	2.3 (2.3)	2.5 (3.2)	2.3	2.6
Strenuous	1.3 (2.0)	0.7 (1.4)	1.1	0.9

Note. NA = not applicable for covariate analyses. CSA = Computer Sciences Applications Inc uniaxial accelerometer/activity monitor (Model 7164, Shalimar, Fla).
[a]n = 52 for self-reported walking outcomes.
*high walkability > low walkability, all $P < .05$; **high walkability > low walkability, all $P < .01$;

ment buildings of over 3 stories (low frequency in both neighborhoods) existed.

The high-walkability neighborhood had higher scores on 6 of the 8 perceived-environment subscales, including all 4 variables on which neighborhood selection was based: residential density, land use mix–diversity, land use mix–access, and street connectivity. Differences between neighborhoods were sometimes subtle because of geographic proximity and shared governance; thus, the ability of respondents to perceive differences provided strong support for the validity of subscale constructs.

Surprisingly, the low-walkability neighborhood residents reported greater numbers of walking/cycling facilities. The walking/cycling facilities subscale had the lowest reliability and was directed toward assessing sidewalks (presence, separation from street) and accessibility of walking/cycling trails, factors that were not used for neighborhood selection. Crime safety also was not used in neighborhood selection and, not surprisingly, did not differ between neighborhoods. Neighborhood environment characteristics assessed are associated with walking and cycling trips for transport,[9] but the psychometrics of the measures of these constructs had not previously been systematically assessed in either the transportation or the health research.

Our study sought to provide a preliminary test of the oft-stated hypothesis that neighborhood walkability,[8,13,22] as defined by land use and community design, is related to physical activity and body weight. Although this study was based on a small sample, it was the first to objectively measure and document the association between neighborhood design and physical activity. Our study extended the transportation research findings by suggesting that higher nonmotorized transport rates in high-walkability neighborhoods may contribute to significantly greater total physical activity.[9]

No observed difference was found between neighborhoods regarding self-reported walking for exercise, self-reported leisure time physical activity, or objectively measured vigorous physical activity. There was, however, a difference between neighborhoods regarding walking for errands. This difference is consistent with transportation research that finds no differences in walking for exercise but finds significant differences in walking for transport purposes between high- and low-walkability neighborhoods.[23] Other types of utilitarian walking in our study—to or from work or school and to or from transit—were infrequent in both neighborhoods, which is consistent with previous research.[24]

On the basis of accelerometer values, residents in the high-walkability neighborhood engaged in approximately 70 more minutes of moderate to vigorous physical activity per week than did the residents in the low-walkability neighborhood. Virtually all the difference in neighborhood-based physical activity was in moderate-intensity activity, which suggests that activities such as walking accounted for the total physical activity difference between neighborhoods. The average person in a high-walkability neighborhood may be meeting the physical activity guidelines of at least 30 minutes of physical activity per day on 2 or more days per week.[25] A 70-minute-per-week difference in physical activity translates to walking 3 miles more per week given an approximate 20-minute-per-mile pace. Over the course of a year, this amount of walking would yield about 15 000 kilocalories of energy expenditure for a 68-kilogram person, which, if not offset by caloric intake, could result in almost 1.8 kilograms of weight loss.

Consistent with the physical activity differences, there was a significant difference between neighborhoods in overweight prevalence (i.e., >25 kg/m^2), with 60% of low-walkability neighborhood residents being overweight, but (similar to alarming US prev-

alence estimates[26,27]) only 35% of high walkability neighborhood residents being overweight. Our findings provide preliminary support for the hypothesis that macroenvironmental factors and trends in neighborhood design are contributing to the obesity epidemic.[28,29]

Physical activity levels within the general population may not improve until neighborhoods are made more walkable. Although changing the form of urban areas and guiding neighborhood design decisions are not areas of expertise for most public health professionals, partnerships with diverse disciplines can provide the data and the advocacy needed to make neighborhoods more conducive to physical activity.[7] The extraordinary promise of changing urban form could effect entire community populations on a relatively permanent basis by consistently helping residents reach elusive physical activity goals that are not achieved by individually oriented behavior-change interventions.[2,30]

The NEWS subscales were defined a priori on the basis of previous findings, a conceptual model, and specific hypotheses rather than empirically by factor analyses. Future research needs to evaluate more neighborhood environment variables and the relation between objective measures of environment and perceived environment measures to identify parsimonious, yet accurate, assessments of neighborhood environments. Census tracts have been used previously to define neighborhoods,[31,32] but the defined area of an individual's environment for physical activity is unknown, as is whether individuals are influenced by the environmental characteristics of entire neighborhoods or by the specific areas around residences.[32]

Random selection was used to recruit participants within the neighborhoods in our study, but the low recruitment rate and the demographic differences between the neighborhoods may limit generalizability. The cross-sectional design does not allow us to determine whether neighborhood design caused physical activity differences or whether individuals self-select into neighborhoods according to physical activity opportunities, including walkability. Assessment of residential choice and psychosocial correlates of physical activity need to be included in future physical activity environmental research.[33] Our study was conceived as a pilot investigation, and the restriction to small samples in 2 neighborhoods in 1 city means that neighborhood comparisons of physical activity and BMI should be considered preliminary. Measurement of neighborhood food environments also could significantly augment the understanding of the relation between environment and weight status.[31] Our results indicate a need for larger and more definitive studies of hypotheses regarding the effects of neighborhood design on physical activity, BMI, and other health variables. ■

About the Authors

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Contributors

B.E. Saelens conceptualized and designed the study, organized and supervised data collection and management, completed data analyses, and led the writing of the article. J.F. Sallis conceptualized and designed the study, supervised data collection, and contributed to the writing. J.B. Black and D. Chen were involved in data collection and management, data analysis, and data interpretation. All authors edited drafts of the article.

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Human Participant Protection

This study was approved by the committee for protection of human subjects of San Diego State University. Participants provided written consent.

References

1. Baranowski T, Anderson C, Carmack C. Mediating variable framework in physical activity interventions. How are we doing? How might we do better? *Am J Prev Med.* 1998;15(4):266–297.

2. Orleans CT. Promoting the maintenance of health behavior change: recommendations for the next generation of research and practice. *Health Psychol.* 2000; 19:76–83.

3. Kahn EB, Ramsey LT, Brownson RC, et al. The effectiveness of interventions to increase physical activity: a systematic review. *Am J Prev Med.* 2002;22(4): 73–107.

4. McLeroy KR, Bibeau D, Steckler A, Glanz K. An ecological perspective on health promotion programs. *Health Educ Q.* 1988;15:351–377.

5. Sallis JF, Owen N. Ecological models of health behavior. In: Glanz K, Rimer BK, Lewis FM, eds. *Health Behavior and Health Education: Theory, Research and Practice.* 3rd ed. San Francisco, CA: Jossey-Bass; 2002: 462–484.

6. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med.* 2002;22(3):188–189.

7. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med.* 1998;15(4):379–397.

8. Frank LD. Land use and transportation interaction: implications on public health and quality of life. *J Plann Educ Res.* 2000;20:6–22.

9. Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literature. *Ann Behav Med.* 2003;25:80–91.

10. *Healthy People 2010: Understanding and Improving Health.* Washington, DC: US Dept of Health and Human Services; 2001.

11. Newman PW, Kenworth JR. Transport and urban form in thirty-two of the world's principal cities. *Transportation Rev.* 1991;11:249–272.

12. Booth SL, Sallis JF, Ritenbaugh C, et al. Environmental and societal factors affect food choice and physical activity: rationale, influences, and leverage points. *Nutr Rev.* 2001;59:S21–S39.

13. Chen DD. The science of smart growth. *Sci Am.* 2000; 283(6):84–91.

14. Pikora TJ, Bull FCL, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable audit instrument to measure the physical environment for physical activity. *Am J Prev Med.* 2002;23(3):187–194.

15. Cohen J. *Statistical Power Analysis for the Behavioral Sciences.* 2nd ed. Hillsdale, NJ: Lawrence Erlbaum Associates; 1988.

16. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications Inc accelerometer. *Med Sci Sports Exerc.* 1998;30:777–781.

17. Melanson EL, Freedson PS. Validity of the Computer Science and Applications Inc (CSA) activity monitor. *Med Sci Sports Exerc.* 1995;27:934–340.

18. Sirard JR, Melanson EL, Li L, Freedson PS. Field evaluation of the Computer Science and Applications Inc physical activity monitor. *Med Sci Sports Exerc.* 2000;32:695–700.

19. Nichols JF, Morgan CG, Chabot LE, Sallis JF, Calfas KJ. Assessment of physical activity with the Computer Science and Applications Inc accelerometer: laboratory versus field evaluation. *Res Q Exerc Sports.* 2000;71:36–43.

20. Johnson MF, Sallis JF, Howell MF. Self-report assessment of walking: effects of aided recall instructions and item order. *Meas Phy Educ Exerc Sci.* 2000;4: 1411–155.

21. Godin GR, Shephard RJ. A simple method to assess exercise behavior in the community. *Can J Appl Sports Sci.* 1985;10:141–146.

22. Handy SL, Boarnet MG, Ewing R, Killingsworth RE. How the built environment affects physical activity: views from urban planning. *Am J Prev Med.* 2002; 23(2):64–73.

23. Handy SL. Urban form and pedestrian choices: study of Austin neighborhoods. *Transportation Res Rec.* 1996;1552:135–144.

24. Cervero R, Gorham R. Commuting in transit versus automobile neighborhoods. *J Am Plann Assoc.* 1995;61:210–225.

25. Pate RR, Pratt M, Blair SN, et al. Physical activity and public health: a recommendation from the Centers for Disease Control and Prevention and the American College of Sports Medicine. *JAMA.* 1995;273: 402–407.

26. Mokdad AH, Bowman BA, Ford ES, et al. The continuing epidemics of obesity and diabetes in the United States. *JAMA.* 2001;286:1195–1200.

27. Flegal KM, Carroll MD, Ogden CL, Johnson CL. Prevalence and trends in obesity among US adults, 1999–2000. *JAMA.* 2002;288:1723–1727.

28. Koplan JP, Dietz WH. Caloric imbalance and public health policy. *JAMA.* 2000;282:1579–1581.

29. Swinburn B, Egger G, Raza F. Dissecting obesogenic environments: the development and application of a framework for identifying and prioritizing environmental interventions for obesity. *Prev Med.* 1999;29: 563–570.

30. Dishman RK, Buckworth J. Increasing physical activity: a quantitative synthesis. *Med Sci Sports Exerc.* 1996;28:706–719.

31. Morland K, Wing S, Diez Roux A, Poole C. Neighborhood characteristics associated with the location of food stores and food service places. *Am J Prev Med.* 2002;22(1):23–29.

32. Scribner RA, Cohen DA, Fisher W. Evidence of a structural effect for alcohol outlet density: a multilevel analysis. *Alcohol Clin Exp Res.* 2000;24:188–195.

33. Giles-Corti B, Donovan RJ. The relative influence of individual, social, and physical environment determinants of physical activity. *Soc Sci Med.* 2002;54: 1793–1812.

Housing and Health in Europe: Preliminary Results of a Pan-European Study

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Objectives. The World Health Organization's Regional Office for Europe has undertaken a large study to evaluate housing and health in 7 European cities.

Methods. Survey tools were used to obtain information about housing and living conditions, health perception, and health status from a representative sample of the population in each city.

Results. In Forli, Italy, the first city studied, preliminary findings indicate some important potential links between housing and health.

Conclusions. These findings, when combined with those from the remaining European cities, will likely generate concrete recommendations for the allocation of resources to programs that can improve housing and health. (*Am J Public Health.* 2003;93:1559–1563)

Environmental living conditions, including housing conditions, are among the primary determinants of an individual's health and have attracted the interest of public health scientists since ancient times.[1–3] There is a substantial body of evidence on the health impacts of specific substances found in the housing environment,[4–6] including asbestos, radon, lead, molds, and volatile organic chemicals (VOCs).[7–12] Housing conditions such as air pollution levels and condensation may contribute to seasonal fluctuations in cardiovascular and respiratory mortality.[13,14] The home is where accidents frequently occur. In the European Union, more than half of the 20 million home and leisure-related accidents that occur each year take place in or around the home.[15]

There is less documentation about the relationships among housing conditions, lifestyles, and health. Recent research has focused on specific individual risk factors and housing elements,[4] whereas the link between housing and psychosocial and mental health issues has been relatively neglected.[16]

Few reports exist about the "global" housing conditions of the European population.[17] In both the western and eastern parts of the European Region of the World Health Organization, social, political, and economic changes have affected housing environments and their impacts on health. For example, the quality of outdoor air and drinking water has improved in many big cities, but noise has worsened all over the continent.[18–20]

In Western Europe, many countries are undergoing fast decentralization, and local authorities have been given more responsibility for housing as a result. Many countries have a large stock of 25- to 30-year-old housing from the postwar reconstruction era that is now showing signs of age. New lifestyles, including a heavy reliance on automobiles, are emerging, and a large proportion of the European population lives in cities lacking the infrastructure required by these lifestyles.

The new political and economic situations that have emerged in Central and Eastern Europe since the fall of the Berlin Wall have created dramatically new housing situations. The percentage of homeowners has increased to more than 95% in some countries.[21] An emerging affluent middle class and a large population living close to or below the poverty level have led to a new stratification of cities. An unprecedented energy crisis, a near-total absence of regulation for condominium management, and the absence of a tradition for maintaining private and commonly shared properties—which were previously maintained by a state organization—have led to (1) a new distribution of housing conditions (e.g., an increased number of bad houses and an emerging new stock of high-luxury houses), (2) an accelerated deterioration of the housing stock, and (3) dramatic changes in the urban landscape.[22,23]

Aware of these trends, the World Health Organization's (WHO) Regional Office for Europe embarked on a study to review and, when needed, enlarge the body of evidence regarding the relationship between housing conditions and health. An informal working group was convened to discuss the health effects that could be influenced by housing conditions and to identify any confounding factors that could mask these effects during a study.[24] This group provided recommendations on which factors in a housing complex should be surveyed. The group also recommended how those factors should be measured to draw conclusions about possible cause–effect relationships. A symposium took place in Bonn, Germany, to validate the study.[25]

Our study started with a pilot project during the winter of 2000 in selected neighborhoods in Schwedt-Oder, Germany; Vilnius, Lithuania; and Bratislava, Slovakia, containing dwellings made of pre-fabricated blocks. The pilot project focused on a housing type that was deemed likely to provide the most inadequate housing conditions. It identified major gaps in the survey tools that were developed for analyzing both housing conditions and health conditions of the inhabitants. The project helped local authorities throughout Europe to identify the qualitative housing needs of their citizens. The results of the pilot project informed the development of the current study.

Study Objectives

The current project has several objectives. First, it seeks to establish clearer links between housing conditions and health. There is strong evidence of the link between health and such substances as radon, asbestos, and formaldehyde. But many other associations lack strong evidence, including the impact of indoor temperature and the quality of indoor air on respiratory and other systems, the influence of housing conditions on mental health, and the pathogenicity of chronic noise exposure in homes. This study will examine those issues.

Second, the results of this study will provide the Ministers of Health and Environment of the

WHO's Regional Office for Europe with a basis for a discussion of housing during the next Environment and Health Ministerial Conference, which is scheduled to be held in Budapest in June 2004. During the conference, the ministers will examine the issue of housing and health in the European region. The evidence from this study will allow the ministers to endorse strong resolutions for government housing policies that favor health and are environmentally sustainable.

Third, this study will provide local authorities with instruments they can adopt and use to better understand both their housing stocks and the influence that existing housing conditions have on the health of their citizens. The instruments also will help local authorities to identify housing priorities that can be satisfied through local policies and projects. These instruments must be accessible at a reasonable cost, and local experts or consultants must be able to use them readily.

Fourth, officials in the participating cities will be given a diagnosis of their housing stocks. They will learn about residents' perceptions about housing conditions, and they will receive a preliminary assessment of the possible impacts those conditions may have on residents' health. These diagnoses will help the officials adjust their housing policies to ensure that the policies are oriented toward achieving significant gains in improved health.

Finally, where possible, the dose–effect relationship between given housing conditions, or a mix of housing conditions, and health will be quantified. In other words, the groundwork will be laid for calculating a first estimate of the global burden of disease resulting from housing conditions.[26]

METHODS

Terminology

Four factors were examined under the general term *housing conditions*—the house, the home, the immediate neighborhood, and the community—and these factors formed the working bases for identifying potential impacts on health.[4] The *house* represents the actual physical shelter in which an individual lives and includes such variables as heating adequacy and maintenance of the structure. The *home* (or the household) consists of all individuals living under the same roof and includes such variables as family size, lifestyle of household residents, and socioeconomic status. The *immediate neighborhood* comprises commonly shared spaces—such as the elevators, staircases, waste chutes, and cellars—and the close vicinity of the house, including the green space around the building, parking spaces, and the pavement immediately outside the building.[27] The *community* means those individuals identified as neighbors by the residents.

Sampling Method

The sample in each city was randomly generated. A list of the target survey population was selected from the residents' registry in Germany, Lithuania, Italy, and Portugal; in all surveyed cities a list of the target population was selected from the residents' registry. In Angers, France, where these registers are inaccessible for legal reasons, we selected the sample from the cadastre (an official register of the quantity, value, and ownership of real estate used in apportioning taxes). A random-number generator assigned a number to each person on the list; these random numbers were then sorted in ascending order. The first 800 to 1300 persons (depending on the expected nonanswer rate) on the list who were living in different dwellings were selected for the survey.

Data Collection

We used 3 survey tools to assess housing conditions and their links to health status. First, a housing questionnaire was used to collect subjective data during a face-to-face interview with the occupant who received the surveyor. This questionnaire addressed the respondent's perception of his or her house, home, immediate neighborhood, and community, and it gathered general information about the building, the socioeconomic status of the household, the housing-related costs, and the lifestyles of the inhabitants. The respondent was used as a proxy for all other members of the household.

Second, trained surveyors used inspection sheets to record their observations about housing conditions and the immediate environment. No measurements were made of variables such as temperature, humidity, and noise during the survey. Because of the international nature of the project, the technical constraints—and the financial limitations—would have increased the complexity beyond what the available resources allowed. Instead, we relied on visible consequences of these measurable factors (e.g., the presence of molds, draft-proofing devices, and supplemental heating devices), which were noted on the inspection sheets.

Third, each occupant of the dwelling was asked to complete a health questionnaire. We collected data about each resident's self-perceived health as well as descriptive information about his or her health status. Whenever possible, the health questionnaire was completed while the surveyor was in the dwelling; for occupants who were not present, questionnaires were left and collected later. In rare cases, a stamped, preaddressed envelope was provided.

The surveyors were either students in a field related to health or housing or students who had previously worked for the national census. They were recruited for the survey period, which lasted 10 to 25 days, depending on the sample size. All surveyors attended a 3-day training seminar that was taught by the same trainers in all cities. This training included a 1-day practical phase to reduce interrater variability.

Each evening, all completed questionnaires were examined; in the case of inaccurate or incomplete questionnaires, the surveyors were asked to make corrections the next morning. For quality assurance, the surveyors were checked randomly in the field, and 4 households per survey team were contacted by phone to verify the collected data. A software company was hired to develop a data entry program that would reduce language-related problems. Single data entry was used with a systematic validation of around 15% of the previous day's work; if a member of the data entry staff was found to have made more than 1 mistake, all of his or her work was double-checked. Finally, the ASCII file generated from the entered data was imported into SPSS (SPSS Inc, Chicago, Ill) for further analysis.

RESULTS FROM FORLI, ITALY

The results presented here are preliminary and represent a very small subset of the data that can be expected from this survey. Additional analyses are being conducted and will be conducted for these data and the data collected

in other survey cities. Many more results will be presented to local leaders in survey cities and in future literature.

Response Rates

Eight hundred households were contacted initially by mail and then by telephone or by a first visit by a team of 2 surveyors; 403 households agreed to participate. Of the residents living in dwellings in which at least 1 person agreed to complete the health questionnaire and the housing questionnaire was completed, 95.6% (n=1172) also completed health questionnaires. The best response rates were among people aged 45 to 60 years and among those with households of more than 3 members. People with higher socioeducational background and well-maintained houses also seemed more willing to participate.

According to the surveyors, residents had a variety of reasons for not participating. Among older residents (age not specified) who did not participate, fear that the surveyors had criminal intentions was the primary reason; younger residents (age not specified) reportedly did not want to spend time. Other reasons included fear that unauthorized construction would be discovered, belief that the house or the health of its occupants were perfect, the fact that the survey was not compulsory, and the lack of interest in any kind of survey. Additionally, some of the residents in the sample had moved or died.

Household Size

The average household size in our sample was 3.0 persons per dwelling, whereas the average household size in Forli was 2.4 persons. This overrepresentation of large families is the result of the sampling procedure. The results are based on a nonstandardized sample.

Housing Conditions

Adverse stairway conditions. On the basis of both residents' perception and surveyors' observations, the frequency of adverse stairway conditions, such as height differences, broken steps, and the absence of handrails, was high. Of the 403 dwellings in our sample, 157 had inside steps or stairs, 14.6% of which had no handrails and 3.8% of which had damaged or loose steps. Of the 315 accidents reported in sample households, 88 (27.9%) were related to falls, which primarily occurred among younger residents, aged 0–19 years (n=41) and older (n=20) residents, aged 60 years and older.

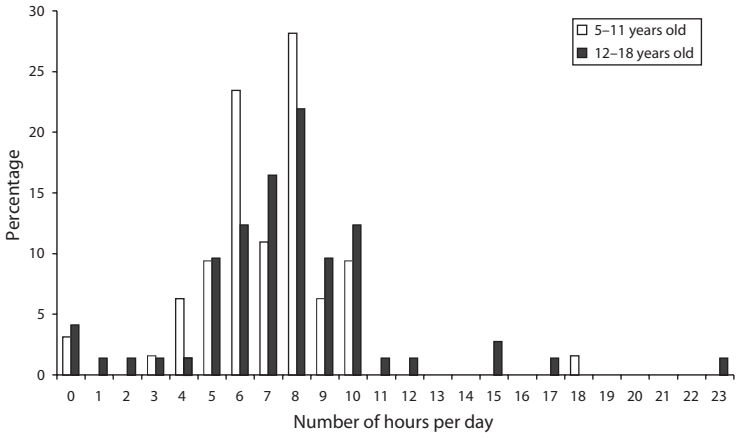

FIGURE 1—Amount of time children and teenagers spend outside of their dwellings during weekdays in Forli, Italy.

Time away from home and physical activity among children and teens. Figure 1 shows the time children (aged 5–11 years) and teenagers (aged 12–18 years) spent away from their dwellings. More than three quarters spent 8 hours or less per day out of their homes; the time at home was spent sleeping, eating meals, doing homework, and watching television. This finding was confirmed by the responses to the questionnaire: 37.6% of the children reported participating in no sports at all or participating only occasionally, and only 21% exercised intensively on a regular basis.

Mold growth. Molds were present in 11.7% of the kitchens and 13.9% of the bedrooms. In 4.1% of the bedrooms, the contaminated area was larger than 42 cm by 30 cm.

Noise, air quality, and drafts. The data on perception of noise, indoor air quality, and drafts, and their possible influences on health, confirmed what was found in the pilot project.[28] Many residents reported drafty windows and an inability to maintain a comfortable temperature, and respiratory diseases were more common among those who reported drafts or inadequate heating. The prevalence of respiratory disease was higher among persons who perceived the air quality in their dwelling to be poor. Noise nuisances also were frequently reported and contributed to lower satisfaction with housing.

Mental health. The pilot project demonstrated that our survey tools were weak in evaluating some of the aspects of mental health. The current survey used instruments such as the Sleep, Anhedonia, Low Self Esteem, Appetite questionnaire,[29] which asks respondents whether they have experienced sleep disturbances, anhedonia (inability to experience pleasure), low self-esteem, or decreased appetite. The preliminary results, which indicated that 9.7% of the total adult population suffers from depression, confirmed figures previously estimated for Italy.[30] An epidemiological analysis is being performed on these data.

Physical activity, body mass index (BMI)*, and proximity to a park.* Findings from the Forli survey indicate that, among adults, persons who live close to a park are more likely than persons living far from a park to engage in regular physical activities (Table 1). Conversely, persons living far from a park are more likely than persons living close to a park to report never exercising. Additionally, the results suggest that persons who live far from a park and who do not exercise regularly are likely to have higher BMIs (Table 2).

DISCUSSION

Preliminary data represent some new and potentially important indications of the links between housing and health. For example, the data show that many children and teenagers spend little time away from their homes

TABLE 1—Relationship Between Exercise and Proximity to a Park Among a Sample Adult Population: Forli, Italy

	Live Less Than 100 Meters From a Park	Live More Than 100 Meters From a Park
Regularly engage in moderate or intense exercise, %	32.7	26.4
Never exercise, %	21.8	24.7

and do not exercise regularly. Is this behavior the result of a lack of green spaces or a lack of sports fields and playgrounds? Is it the result of a lack of organized activities for these age groups? Or is there some other reason for this behavior? The city health authorities in Europe need to investigate this important problem.

Physical activities have an impact on obesity,[31] and the early results support this hypothesis. Among adults, data indicate a link among regular exercise, BMI, and distance from parks. Perhaps when this study is completed, we will be able to demonstrate that lack of access to green space and public parks decreases residents' levels of physical activity and increases their BMIs.

The surveyors found mold in many homes. The most contaminated rooms were bedrooms, where the children—who are most sensitive to allergens—spent the most time. Ideally, information about mold should be analyzed in conjunction with several other considerations: presence or absence of airtight or double-glazed windows, socioeconomic status of the family, complaints about heating expenditures, and presence or absence of allergic diseases, especially asthma. Unfortunately, the sample from the survey was too small for such an analysis; however, this analysis may be possible when the surveys are completed in all of the cities.

The surveyors found problems with the stairways in the sample dwellings. Additionally, more than one quarter of the accidents that occurred in the sample homes were related to falls. Additional analysis is needed to determine whether those falls were linked to adverse stairway conditions. If such a link is found, an economic analysis may lead to a reconsideration of subsidies for housing rehabilitation; large gains in improved health from moderate housing improvements may well be expected from housing rehabilitation.

This survey has a number of limitations that must be considered when interpreting data. First, as in all studies of this nature, the representativeness of the sample is the most crucial issue. In Forli, 403 (50.2%) of the households chosen through random selection agreed to answer the housing questionnaires, and all but 4.4% of the residents living in these dwellings completed the health questionnaire as well. In Vilnius, Lithuania, 688 (62.5%) of the 1100 randomly selected households agreed to complete the housing questionnaire, and 1798 (83.1%) of the 2164 residents living in these dwellings also completed the health questionnaire. Participants' willingness to answer the questionnaires varies from city to city. Further analysis of the nonanswer distribution and its significance to the representativeness of the sample is needed.

During the next survey phase of the study, the surveyors will be asked to complete a questionnaire for each household to determine why some households did not agree to participate. Additionally, the surveyors have suggested that response rates might be improved if sample households received a letter informing them of the survey, signed by the WHO and the mayor of the city, before any other contact is made. The surveyors also suggested that response rates might be improved if the interviewers maintain a pleasant demeanor.

A second limitation of the survey related to the sampling procedure which allowed households to be selected with a probability directly proportional to their size. However, this aspect of the sample can be easily standardized, because the exact distribution of dwellings by number of occupants is known in each city.

Third, the target population within a city includes illegal immigrants, nonregistered persons, and persons who are not represented in our sample. This lack of representation is a shortcoming for targeting specific risk groups. Surely, the population excluded from our study experiences environmental conditions that are much worse than those experienced by the surveyed population. Special studies are being conducted—and more will need be undertaken—to address these groups.[32]

Fourth, this survey procedure did not allow for analysis by neighborhood, because those neighborhoods with a small population will be represented by a very small sample. No adjustments are planned to correct this limitation. Whenever possible, the total sample size was increased to allow neighborhood comparisons.

Fifth, difficulties with the translation and interpretation of the survey tools exist in any international study. We have tried to overcome these difficulties by conducting a systematic pilot project with the translated questionnaires. In each country, 20 households representing elderly, low- and high-education, migrant, urban, and rural populations were or will be selected. Also in each country, an expert in the native language helped answer questions from the surveyors during both the training and the surveying. We did not undertake a reciprocal translation to test the quality of the translation.

Finally, cities in Eastern Europe, the Caucasus, and central Asia are not well represented compared with Western Europe. This lack of representation is a matter of financial restrictions. Perhaps future surveys can address these regions.

When a preliminary analysis of the data from Forli was completed, it was provided to the city council and the local press during a press conference. The release of this information triggered substantial interest both in the media and among city leaders. It is anticipated that the presentation of data in other cities will be met with a similar response. The survey has been completed in 5 cities and is under way in 2 others; officials in a third city have been approached about participating in the survey.

TABLE 2—Relationship Between Body Mass Index (BMI) and Exercise Among a Sample Adult Population Living Near a Park: Forli, Italy

	BMI < 20	BMI = 20–25	BMI = 25–30	BMI > 30
Live close to a park, %	48.8	45.9	40.3	37.2
Regularly engage in moderate or intense exercise, %	32.8	33.7	23.9	16.0

The data have not yet been fully analyzed or transferred into a usable database.

CONCLUSIONS

The main conclusion of this preliminary phase is that this type of cross-sectional study satisfies the expectations of the city council and generates interest from the local press and the public. The preliminary phase of the study also reveals the important potential links between housing and health and will likely generate concrete recommendations about the following: mental health and housing; poverty, housing, and health; noise and health; allergies and housing; perceptions of housing conditions and associated perceptions of health; and immediate-environment conditions and health status.

We anticipate that the recommendations developed as a result of the survey data will guide policies related to housing and health not only in the survey cities but also in cities worldwide. For example, survey results will help local and national authorities identify areas in which housing rehabilitation programs will achieve the greatest gains in improved health. The survey results also will (1) help set priorities within these programs, (2) help policymakers develop new, and revise existing, legislation related to both new housing and rehabilitated housing, (3) demonstrate how the immediate environment can affect health, and (4) help community leaders better address housing conditions in their area to improve the health of the population. The results also may help community groups develop effective health education and accident prevention programs. Finally, if a dose–effect relationship, or at least a causal link, can be established between housing and health, the results of this study may establish the economic value of gains in improved health that can be achieved by improving housing conditions. ■

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Contributors

X.R. Bonnefoy coordinated the work and is the main author of the text. M. Braubach designed the pilot study and contributed significantly to the design of the survey tools concerning housing and environmental conditions. B. Moissonier coordinated and performed most of the data analysis. K. Monolbaev developed the health and energy efficiency aspects of the questionnaire. N. Röbbel conducted the field work and prepared the first report to the city council of Forli.

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No protocol approval was needed for this study.

References

1. Foster HD. *Health, Disease and the Environment.* London, England: Belhaven Press; 1992.

2. Ineichen B. *Homes and Health: How Housing and Health Interact.* London, England: E & FN Spon; 1993.

3. Krieger J, Higgins DL. Housing and health: time again for public health action. *Am J Public Health.* 2002;92:758–768.

4. Fuller-Thomson E, Hulchanski JD, Hwang S. The housing/health relationship: what do we know? *Rev Environ Health.* 2000;15(1–2):109–133.

5. Braubach M, Bonnefoy X. Housing and health: the Eastern European challenge. *Open House Int.* 2001; 26(2):8–22.

6. Ranson R. *Healthy Housing—A Practical Guide.* London, England: E & FN Spon; 1991.

7. *Chrysotile Asbestos.* Geneva, Switzerland: World Health Organization; 1998. Environmental Health Criteria 203.

8. *Radon.* Copenhagen, Denmark: World Health Organization; 1996. Health and environment briefing pamphlet series 10.

9. Schwartz J. Low-level lead exposure and children's IQ: a meta-analysis and search for a threshold. *Environ Res.* 1994;65:42–55.

10. Reijula K. Exposure to Microorganisms: Diseases and Diagnosis. *Indoor Air.* 1998;(suppl 4):40–44.

11. Gravesen S, Nielsen PA, Iversen R, Nielsen KF. Microfungal contamination of damp buildings—examples of risk constructions and risk materials. *Environ Health Perspect.* 1999;107(suppl 3):505–508.

12. *Assessment of Exposures to Indoor Air Pollutants.* Copenhagen, Denmark: World Health Organization; 1997. European Series, No 78.

13. Wilkinson R, Landon M, Armstrong B, Stevenson S, McKee M, Fletcher T. *Cold Comfort: The Social and Environmental Determinants of Excess Winter Death in England, 1986–1996.* Bristol, England: The Policy Press; 2001.

14. Markus TA. Cold, condensation and housing poverty. In: Burridge R, Ormandy D, eds. *Unhealthy Housing: Research, Remedies, and Reform.* London, England: E & F N Spon; 1993:141–167.

15. Ranson R. Accidents at home: the modern epidemic. In: Burridge R, Ormandy D, eds. *Unhealthy Housing: Research, Remedies, and Reform.* London, England: E & F N Spon; 1993:223–255.

16. Dunn JR. Housing and health inequalities: review and prospects for research. *Housing Stud.* 2000;15(3): 341–366.

17. Lawrence RJ. Urban health: a new agenda? *Rev Environ Health.* 2000;15(1–2):1–12.

18. World Health Organization, European Centre for Environment and Health. *Concern for Europe's Tomorrow: Health and Environment in the WHO European Region.* Stuttgart, Germany: Wissenschaftliche Verlagsgesellschaft; 1995.

19. Berglund B, Lindvall T, Schwela D, Goh KT, eds. *World Health Organization: Guidelines for Community Noise.* Singapore: Institute of Environmental Epidemiology; 2000.

20. European Union. *Green Paper on Future Noise Policy.* Brussels, Belgium: European Union; 1996.

21. *Country Profiles on the Housing Sector: Lithuania.* New York, NY: United Nations Economic Commission for Europe.; 2000.

22. United Nations Economic Commission for Europe. *Guidelines on Condominium Ownership of Housing for Countries in Transition.* New York, NY/Geneva, Switzerland: UNECE; 2002.

23. Hunger B. Die Bedeutung großer Neubaugebiete in der Wohnungs- und Städtebaupolitik der DDR—historischer Rückblick [The meaning of large modern estates in the urban planning and housing policies of the German Democratic Republic—historical review]. *Inf Raumentwickl.* 1994;9:595–609.

24. World Health Organization. *Proceedings of the WHO Expert Meeting on Integrated Approaches to Housing and Health,* Paris, France; July 12–13, 2000.

25. World Health Organization. *Proceedings of the WHO Symposium on Housing and Health in Europe,* Bonn, Germany; June 6–8, 2001.

26. Murray CJL, Lopez AD, eds. *The Global Burden of Disease: A Comprehensive Assessment of Mortality and Disability From Diseases, Injuries, and Risk Factors in 1990 and Projected to 2020.* Cambridge, MA: Harvard University Press; 1996.

27. Marans RW. The perceived quality of residential environments: some methodological issues. In: Craik K, Zube I, eds. *Perceiving Environmental Quality: Research and Applications.* New York, NY: Plenum Publishing Corporation; 1976:123–147.

28. Bonnefoy X, Braubach M, Krapavickaite D, Ormandy D, Zurlyte I. Housing conditions and self-reported health status: a study in panel block buildings in three cities. *J Housing Built Environment.* In press.

29. Brody DS, Hahn SR, Spitzer RL, et al. Identifying patients with depression in the primary care setting: a more efficient method. *Arch Intern Med.* 1998;58(22): 2469–2475.

30. Lépine J-P. Epidemiology, burden and disability in depression and anxiety. *J Clin Psychiatry.* 2001; 62(suppl 13);4–10.

31. *Obesity: Preventing and Managing the Global Epidemic.* Geneva, Switzerland: World Health Organization; 2000. WHO Technical Report Series, No. 894.

32. Breakey WR. It's time for the public health community to declare war on homelessness. *Am J Public Health.* 1997;87:153–155.

Mortality Risk Associated With Leaving Home: Recognizing the Relevance of the Built Environment

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Objectives. I analyzed traffic fatalities and homicides related to leaving home for routine activities, and considered connections between these fatalities and the built environment.

Methods. I analyzed city, county, state, and federal data for traffic fatalities and homicides by strangers for 15 metropolitan areas, and classified deaths as occurring in the central city, in inner suburbs, or in outer suburbs (exurbs).

Results. Traffic fatality rates were highest in exurban areas. Combined traffic fatality and homicide-by-stranger rates were higher in some or all outer counties than in central cities or inner suburbs in all of the metropolitan areas studied.

Conclusions. Traffic fatalities are largely unrecognized as a danger to be factored into residential location decisions. Land use controls that deter sprawl along narrow exurban roads can reduce the mortality risks associated with leaving home. (*Am J Public Health.* 2003;93:1564–1569)

For many years, traffic accidents have ranked among the top 10 leading causes of death, standing at number 7 in 2000. Therefore, they have significant implications for desirable and undesirable patterns of the built environment. In a society in which transportation mobility is a prominent feature of everyday existence, dangers to health related to transportation are worth considering. When transportation dangers are conceptualized to include the danger of leaving home to conduct routine activities, additional implications of built environment patterns can be analyzed. Here I analyze the most numerous and measurable of deaths related to leaving home for routine activities—traffic fatalities and homicides—and consider connections between them and the built environment.

Traffic fatalities are by far the most important contributor to the danger of leaving home. In 2000, traffic fatalities[1(p15)] were 2.7 times more numerous than homicides (41 821 vs 15 517).[2] The ratio of traffic fatalities to homicides had increased considerably since 1991, when there were 41 508 traffic fatalities,[1(p15)] 1.7 times more fatalities than the 24 700 homicides.[2] The number of traffic fatalities has varied since 1991, from a low of 39 250 in 1992[1(p15)] to a high of 42 116 in 2001,[3(p4)] whereas the number of homicides decreased throughout the 1990s until 2000, when it increased slightly, to 15 980, between 2000 and 2001.[4]

I considered some but not all homicides in this analysis, because many homicides are related to dangers at residences and workplaces rather than to daily travel. Most homicides are committed by family members, other relatives, friends, acquaintances, and coworkers. In these instances, danger is associated more with being at home, at work, or at a friend's residence, rather than with routine daily mobility. In this analysis, I selected traffic fatalities and homicides by strangers as the best guides to dangers of leaving home. I then considered the circumstances under which these mortality risks are encountered in cities, inner suburban counties that border central cities, and outer suburban (exurban) counties that touch nonmetropolitan counties.[5] These findings have implications for citizens deciding where to live, developers deciding where to build, and public officials deciding which patterns of development to encourage and discourage.

METHODS

I studied the danger of leaving home, as represented by traffic fatalities and homicides by strangers, in 8 large metropolitan areas encompassing 60 counties and 9 central cities for varying periods from 1997 through 2000, and in 7 medium to small metropolitan areas in Virginia for 3 segments of 5 years each: 1993 through 1997, 1988 through 1992, and 1978 through 1982. The 8 large metropolitan areas were Baltimore, Chicago, Dallas, Houston, Milwaukee–Waukesha, Minneapolis–St. Paul, Philadelphia, and Pittsburgh. The 7 medium to small metropolitan areas in Virginia were Charlottesville, Danville, Lynchburg, Norfolk–Virginia Beach, Richmond, Roanoke, and the Virginia part of Washington, DC (comprising 13 cities and counties).

Homicide data included homicides and nonnegligent manslaughters. In calculating rates of homicides by strangers for the 8 large metropolitan areas, I applied state rates to corresponding metropolitan areas when they were available. For Dallas and Houston, stranger-perpetrated homicide data came from the Texas Department of Public Safety.[6] For Minneapolis–St. Paul, stranger homicide data came from the Criminal Justice Information System.[7] For Philadelphia, stranger homicide data came from the New Jersey State Police[8] and the Pennsylvania State Police.[9] For Pittsburgh, stranger homicide data came from the Pennsylvania State Police.[9] For Baltimore, Chicago, and Milwaukee–Waukesha, I used the national rate of homicides by strangers as calculated by the Federal Bureau of Investigation.[2] This figure varied from 20% to 23%. In the course of investigating homicides, police departments determine whether the perpetrator knew the victim. I excluded homicides for which the relationship of perpetrator and victim was not known.

City traffic fatality data for Baltimore, Chicago, Dallas, Houston, Milwaukee–Wausheka, Philadelphia, and Pittsburgh came from the National Highway Traffic Safety Administration (NHTSA).[1] County traffic fatality data for Baltimore, Chicago, Dallas, Houston, Milwaukee–Waukesha, Philadelphia, and

Pittsburgh came from the Fatality Analysis Reporting System (FARS) Web site.[10] Wisconsin county traffic fatality data also came from the Wisconsin Department of Transportation Office of Transportation Safety.[11] City and county traffic fatality data for Minneapolis–St. Paul came from the Minnesota Department of Public Safety Office of Traffic Safety.[12] I used population data from the 2000 census[13] and acreage data from the 1990 and 2000 censuses for the larger metropolitan areas.[13,14]

For each city and county I calculated the rate of traffic fatalities and the rate of homicides by strangers per 10 000 residents and added them to arrive at a combined fatality rate. For the Virginia cities and counties, these were 5-year averages. For the 8 large metropolitan areas, they were 2- to 4-year averages, depending on data availability.

RESULTS

My findings were consistent in 3 spatial dimensions. First, counties with low residential density always had the most traffic fatalities and homicides by strangers in each metropolitan area and each time period and thus were more dangerous than their corresponding central cities. Second, 1 or more suburban counties contiguous to the central city were the least dangerous in each large metropolitan area. Third, in small metropolitan areas in Virginia (Charlottesville, Danville, Lynchburg, Roanoke), the county adjacent to the central city, which contains inner, middle, and outer suburbs, was more dangerous in each instance than the central city itself.

The relationship between low population density and danger becomes evident when all 49 metropolitan counties and cities in the state of Virginia are displayed (Table 1). For the 14 jurisdictions with the highest combined rates of traffic fatalities[15] and homicides by strangers,[16] the highest population density was 0.2 person per acre (143 persons or less per square mile). For the next 10 highest combined rates, only Washington, DC, and Petersburg had population densities higher than 0.6 person per acre (402 persons or less per square mile). Conversely, of the 15 safest cities and counties, only Lynchburg had a population density of less than 2.1 persons per acre. The jurisdiction with the highest population density, Alexandria, with 11.4 persons per acre, was the second safest jurisdiction in Virginia. For 27 counties with population densities from 0.1 to 0.9 person per acre, the mean rate of traffic fatalities and homicides by strangers was 5.2 per 10 000 residents (median=4.9). For the 23 cities and counties with population densities of 1.0 to 11.4 persons per acre, the mean was 1.9 (median=1.5).

Table 2 indicates that similar findings by studies of traffic fatalities and homicides by strangers in 60 counties and 9 cities in 8 metropolitan areas. The 15 most dangerous jurisdictions were exurban counties bordering nonmetropolitan counties with population densities of 0.1 to 0.4 person per acre. The city of Dallas, the 16th most dangerous jurisdiction, tied Houston as the lowest-density central city, with 5.7 persons per acre. In these 8 metropolitan areas, inner suburbs bordering the central city consistently had the fewest traffic fatalities and homicides by strangers. One or more exurban counties consistently had the most, with exurban areas being particularly dangerous compared with inner areas in the Dallas, Houston, Minneapolis–St. Paul, and Pittsburgh metropolitan areas. In the 39 counties with population densities of from 0.1 to 0.9 person per acre, the mean rate of traffic fatalities and homicides by strangers was 1.9 (median=1.6), whereas for the 30 cities and counties with densities of from 1.0 to 19.9 persons per acre, the mean combined fatality rate was 1.3 (median=1.0).

In each metropolitan area, some suburban and exurban counties had higher combined traffic fatality and stranger homicide rates

TABLE 1—Danger Ranking Based on Combined Fatality Rates[a] and Population Density[b] in 7 Metropolitan Areas in Virginia, 1988–1997

Rank From Most to Least Dangerous[c]	Counties and Cities	Combined Fatality Rate (1988–1997)	Population Density (1990)
1	Charles City	11.5	0.1
2	New Kent	9.9	0.1
3	Dinwiddie	8.1	0.1
4	Prince George	7.8	0.2
5	Botetourt	6.7	0.1
5	Fauquier	6.7	0.1
7	Goochland	6.4	0.1
7	Greene	6.4	0.1
9	Pittsylvania	6.3	0.1
10	Clarke	6.0	0.1
11	Suffolk	5.7	0.2
12	Frederick	5.3	0.2
13	Fluvanna	5.2	0.1
14	Spotsylvania	4.9	0.2
15	Powhatan	4.6	0.1
16	Hanover	4.5	0.2
16	Albemarle	4.5	0.1
18	Washington, DC	4.3	13.5
19	Amherst	4.1	0.1
20	Petersburg	4.0	2.6
21	Richmond	3.7	5.7
21	York	3.7	0.6
23	Stafford	3.6	0.1
24	Campbell	3.3	0.1
25	Danville	2.8	1.9
25	Norfolk	2.8	7.6
27	Gloucester	2.7	0.2
27	Loudoun	2.7	0.3
27	James City	2.7	0.4
30	Prince William	2.5	1.0
31	Chesapeake	2.3	0.7
32	Portsmouth	2.2	4.9
32	Lynchburg	2.2	2.1
34	Roanoke (county)	2.1	0.5
34	Newport News	2.1	3.9
36	Henrico	2.0	1.4
36	Chesterfield	2.0	0.8
38	Roanoke (city)	1.9	3.5
39	Hampton	1.5	4.0
39	Virginia Beach	1.5	2.5
39	Fairfax (county)	1.5	3.2
42	Charlottesville	1.3	6.1
42	Hopewell	1.3	3.5
44	Arlington	1.2	10.3
45	Falls Church	1.0	7.5
45	Colonial Heights	1.0	3.3
45	Manassas	1.0	4.4
45	Alexandria	1.0	11.4
49	Fairfax (city)	0.7	4.9
50	Manassas Park	0.0	5.8

[a]Combined traffic fatality and stranger homicide rates, per 10 000 residents.
[b]Persons per acre.
[c]Where ties occurred, the same number is applied to all counties and cities sharing that ranking.

TABLE 2—Traffic Fatality and Homicide Rates in 8 US Metropolitan Areas

Metropolitan Area	Population	Persons per Acre	Traffic Fatalities[a]	Total Homicides[a]	Homicides by Strangers[a]	Traffic Fatalities and Total Homicides[a]	Traffic Fatalities and Homicides by Strangers[a]
Baltimore PMSA (average 1997–1999)	2 552 994	...	...	...	...	...	...
Queen Anne's County	40 563	0.2	2.5	0.2	0.1	2.8	2.6
Carroll County	150 897	0.5	1.4	0.2	0.0	1.6	1.5
Harford County	218 590	0.8	1.2	0.3	0.1	1.5	1.2
Howard County	247 842	1.5	1.1	0.2	0.0	1.2	1.1
Anne Arundel County	489 656	1.8	1.1	0.2	0.0	1.3	1.1
Baltimore County	754 292	2.0	1.0	0.3	0.1	1.3	1.1
Baltimore (city)	651 154	12.6	0.7	4.8	1.0	5.5	1.7
Chicago PMSA (average 1997–2000)	8 272 768	...	...	...	...	...	...
Grundy County	37 535	0.1	3.3	0.1	0.0	3.4	3.3
DeKalb County	88 969	0.2	1.4	0.1	0.0	1.5	1.4
Kendall County	54 544	0.3	1.9	0.0	0.0	1.9	1.9
McHenry County	260 077	0.7	1.2	0.1	0.0	1.3	1.2
Will County	502 266	0.9	1.1	0.3	0.1	1.5	1.2
Kane County	404 119	1.2	0.9	0.6	0.1	1.5	1.1
Lake County	644 356	2.2	0.9	0.2	0.0	1.1	1.0
DuPage County	904 161	4.2	0.6	0.1	0.0	0.7	0.6
Cook County excluding Chicago	2 480 727	5.4	0.7	0.3	0.1	1.0	0.8
Cook County including Chicago	5 376 741	8.9	0.8	1.4	0.3	2.2	1.1
Chicago	2 896 016	19.9	0.9	2.4	0.5	3.2	1.4
Dallas PMSA[b] (average 1999–2000)	3 519 176	...	...	...	...	...	...
Henderson County	73 277	0.1	2.6	0.7	0.2	3.3	2.8
Kaufman County	71 313	0.1	4.4	0.7	0.2	5.1	4.6
Hunt County	76 596	0.1	3.7	0.5	0.1	4.1	3.8
Ellis County	111 360	0.2	2.6	0.4	0.1	3.1	2.7
Rockwall County	43 080	0.5	1.0	0.0	0.0	1.0	1.0
Denton County	432 976	0.8	0.9	0.1	0.0	1.0	0.9
Collin County	491 675	0.9	1.0	0.1	0.0	1.1	1.0
Dallas County	2 218 899	3.9	1.1	1.1	0.3	2.2	1.4
Dallas (city)	1 188 580	5.7	1.4	1.8	0.4	3.2	1.9
Dallas County excluding City of Dallas	1 097 768	...	0.8	0.3	0.1	1.1	0.8
Houston PMSA[c] (average 1999–2000)	4 177 646	...	...	...	...	...	...
Chambers County	26 031	0.1	4.2	0.4	0.1	4.6	4.3
Liberty County	70 154	0.1	3.0	0.4	0.1	3.4	3.1
Waller County	32 663	0.1	3.8	0.8	0.2	4.6	4.0
Montgomery County	293 768	0.4	2.3	0.4	0.1	2.7	2.4
Fort Bend County	354 452	0.6	0.8	0.3	0.1	1.1	0.9
Harris County	3 400 578	3.1	1.1	0.9	0.2	2.0	1.3
Houston	1 953 631	5.7	1.2	1.2	0.3	2.4	1.5
Harris County excluding Houston	1 480 789	...	1.0	0.4	0.1	1.3	1.1
Milwaukee–Waukesha PMSA (average 1997–1999)	1 500 741	...	...	...	...	...	...
Washington County	117 493	0.4	1.3	0.1	0.0	1.4	1.3
Ozaukee County	82 317	0.6	0.8	0.0	0.0	0.8	0.8
Waukesha County	360 767	1.0	0.8	0.0	0.0	0.8	0.8
Milwaukee County excluding City of Milwaukee	343 190	3.7	0.5	0.1	0.0	0.6	0.5
Milwaukee County including City of Milwaukee	940 164	6.1	0.5	1.3	0.3	1.8	0.8
Milwaukee (city)	596 974	9.7	0.6	2.0	0.4	2.5	1.0

Continued

TABLE 2—*Continued*

Minneapolis–St Paul MSA (average 1997–2000[d])	2 968 806	. . .	. . .	. . .	. . .	. . .	. . .
Pierce County	36 804	0.1	1.6	0.1	0.0	1.7	1.6
Isanti County	31 287	0.1	1.8	0.1	0.0	1.8	1.8
St. Croix County	63 155	0.1	2.5	0.0	0.0	2.5	2.5
Chisago County	41 101	0.2	2.1	0.2	0.0	2.4	2.2
Wright County	89 986	0.2	1.7	0.1	0.0	1.8	1.7
Sherburne County	64 417	0.2	1.5	0.0	0.0	1.6	1.5
Carver County	70 205	0.3	1.6	0.1	0.0	1.7	1.6
Scott County	89 498	0.4	1.8	0.1	0.0	1.9	1.9
Washington County	201 130	0.8	0.6	0.0	0.0	0.7	0.6
Dakota County	355 904	1.0	0.8	0.1	0.0	0.8	0.8
Anoka County	298 084	1.1	0.8	0.2	0.0	1.0	0.8
Hennepin County excluding Minneapolis	733 582	2.3	0.5	0.1	0.0	0.6	0.5
Hennepin County including Minneapolis	1 116 200	3.1	0.5	0.5	0.1	1.0	0.6
Ramsey County excluding St Paul	223 884	3.4	0.6	0.1	0.0	0.7	0.6
Ramsey County including St Paul	511 035	5.1	0.6	0.5	0.1	1.0	0.7
St Paul	287 151	8.5	0.6	0.7	0.1	1.3	0.7
Minneapolis	382 618	10.9	0.5	1.4	0.3	1.9	0.8
Philadelphia PMSA (average 1997–1999)	5 100 931	. . .	. . .	. . .	. . .	. . .	. . .
Salem County	64 285	0.3	2.7	0.4	0.1	3.1	2.8
Burlington County	423 394	0.8	1.2	0.2	0.0	1.4	1.2
Chester County	433 501	0.9	1.2	0.2	0.0	1.4	1.2
Gloucester County	254 673	1.2	1.5	0.2	0.0	1.6	1.5
Bucks County	597 635	1.5	1.1	0.1	0.0	1.2	1.1
Montgomery County	750 097	2.4	0.8	0.2	0.0	1.0	0.8
Camden County	508 932	3.6	0.9	0.8	0.2	1.7	1.1
Delaware County	550 864	4.7	0.7	0.4	0.1	1.0	0.8
Philadelphia City/County	1 517 550	17.6	0.8	2.3	0.5	3.1	1.3
Pittsburgh MSA (average 1997–1999)	2 358 695	. . .	. . .	. . .	. . .	. . .	. . .
Fayette County	148 644	0.3	2.0	0.3	0.1	2.2	2.0
Butler County	174 083	0.3	1.4	0.2	0.0	1.5	1.4
Washington County	202 897	0.4	1.2	0.2	0.0	1.4	1.3
Westmoreland County	369 993	0.6	1.2	0.2	0.0	1.4	1.2
Beaver County	181 412	0.7	1.0	0.3	0.1	1.2	1.0
Allegheny County excluding Pittsburgh	947 103	2.2	0.6	0.2	0.0	0.8	0.6
Allegheny County including Pittsburgh	1 281 666	2.7	0.6	0.5	0.1	1.1	0.7
Pittsburgh	334 563	10.0	0.7	1.3	0.3	2.1	1.0

Note. PMSA = primary metropolitan statistical area; MSA = metropolitan statistical area.
Source. Adapted from Lucy and Rabalais.[16]
[a]Per 10 000 population.
[b]Although small portions of the city of Dallas lie within Collin, Denton, and Rockwall Counties, all homicides and traffic fatalities within the city of Dallas were attributed to the much larger portion of the city within Dallas County.
[c]Although small parts of Houston lie within Fort Bend and Montgomery Counties, homicides and traffic fatalities within the City of Houston were attributed to that part of the city within Harris County.
[d]Data were unavailable for some counties for 2000; average reflects 1997–1999 totals.

than did the central city. In the Chicago metropolitan area, for example, the combined death rate from traffic fatalities and homicides by strangers was higher (1997–2000) in DeKalb, Grundy, and Kendall counties than in the city of Chicago and was similar to rates in McHenry and Will counties. In the Dallas area, the traffic and stranger homicide death rate was higher (1999–2000) in Ellis, Henderson, Hunt, and Kaufman counties than in the city of Dallas. In the Houston area, the combined death rate was higher (1999–2000) in Chambers, Liberty, Montgomery, and Waller counties than in the city of Houston. In the Minneapolis–St. Paul metropolitan area, the combined rate was higher (1997–2000) in the counties of Carver, Chisago, Isanti, Pierce, Scott, Sherburne, St. Croix, and Wright than in the central cities. In the Pittsburgh metropolitan area, the combined rate was higher (1997–1999) in the counties

of Beaver, Butler, Fayette, Washington, and Westmoreland than in the central city.[17]

DISCUSSION

The exurbs are the most dangerous parts of metropolitan areas, because more cars move fast on 2-lane roads, where dangers of driver impairment, mistakes, and inattention compound the dangers. In 2000, for example, 28 544 out of 37 409 fatal crashes occurred on 2-lane roads, and 24 021 were on roads that were not divided.[1(p53)]

Risk of fatal accidents generally is associated with speed. Only 10.3% of fatal accidents occurring in 2000 were in speed zones of 30 miles per hour or less, compared with 52.7% of fatalities occurring in speed zones of 55 miles per hour or more.[1(p51)] Multiple factors contributing to fatal accidents are recorded by the NHTSA. More than half of those factors are related to speed, either excessive speed for the road conditions or mistakes in driving that were more likely owing to high speed.[1(p100)] Research has confirmed that people who drive farther, such as long-distance commuters, also drive faster.[18]

A large proportion of traffic fatalities occur in rural areas. In 2000, 21 521 fatal crashes were in rural areas, 14 667 were in urban areas, and 1221 were in unassigned locations.[1(p52)] In 2000, the highest statewide traffic fatality rates were in low-density Southern and Western states—Mississippi, Montana, Louisiana, South Carolina, and Arkansas. And the lowest rates were in what are for the most part highly urbanized Northeastern states—Massachusetts, Rhode Island, New Hampshire, New York, Connecticut, and New Jersey.[1(p178)] Their death rates were 2 to 3 times lower than rates in the low-density states with high traffic fatality rates. A study of effects of low-density suburban sprawl in 83 metropolitan areas found that traffic fatality rates were 50% higher in the 10 most sprawling than in the 10 least sprawling metropolitan areas—a rate of 36 fatalities, compared with 23, per 100 000 residents.[19]

Obstacles to emergency care also make exurban and rural areas more dangerous. According to NHTSA data, of 9274 fatal crashes for which emergency vehicle trip duration was identified, deaths occurred in only 747 instances in which the victim arrived at the hospital within 20 minutes or less of the time of the crash.[1(p48)] However, the median emergency vehicle travel time to hospitals in fatal rural crashes was nearly 50 minutes.[1(p48)] In 2000, the time from crash to hospital arrival was more than 40 minutes in 68.7% of fatal rural crashes, whereas the time from crash to hospital arrival exceeded 40 minutes in 29.7% of fatal urban crashes.[1(p48)]

The method of analysis used here may understate dangers in exurban counties. Traffic fatalities are recorded for the county or city where the accident occurred, not where the victim lived. Commuting and other travel is greater from outer counties to inner counties and central cities than the reverse. Therefore, it is more likely that victims in inner suburbs and central cities are residents of outer counties than that victims in outer counties are residents of central cities and inner counties. Daily travel patterns would increase the recorded traffic fatality rate in inner suburbs and central cities.

One puzzling question about traffic fatalities is why the totals remained around 40 000 per year during the 1990s,[1(p15)] when air bags became standard equipment on automobiles, driving-under-the-influence laws were strengthened across the nation, and seat belt use reached high levels. The fatality rate dropped substantially with respect to population from 1973 (25.5 fatalities per 100 000 population) through 1992 (15.4 per 100 000 population). It increased to 15.9 per 100 000 in 1995 and 1996 and then decreased to 15.2 per 100 000 by 2000.[1(p15)]

Seat belt use by drivers in fatal crashes increased rapidly, from 6% in 1984 to 40% in 1991, then slowly to 55.5% in 2000.[1(p39)] Seat belt use by passengers in fatal crashes also continued to increase, from 24% in 1991 to 36% in 2000.[1(p40)] Seat belt use by occupants who were injured was 81% in 2000, up from 64% in 1991.[1(p40)] These differences in seat belt use between occupants in fatal and injury accidents are consistent with the goal of recommending or requiring seat belt use to prevent death and reduce injuries. At the same time, the fact that seat belts were used by 55.5% of drivers who died in motor vehicle accidents[1(p39)] clearly indicates that restraints are not sufficient protection. One possible explanation for the stable, rather than decreasing, fatality rate despite greater use of seat belts is that an increase in exurban population has put more drivers in harm's way and increased the number of drivers who are driving fast as a response to traffic delays and are stressed from spending too much time in motor vehicles.

Sprawl settlement patterns result in housing construction in dangerous exurban settings. This outcome is curious, because safety is widely believed to be a prominent determinant of residential location decisions. In a 1999 survey by the National Association of Home Builders,[20] neighborhood crime rate was by far the most frequently cited neighborhood influence on residential location decisions—more than 80% of respondents rated it as very important. By contrast, only 5% to 33% of respondents cited neighborhood factors, such as public transportation, highway access, and shopping locations, as important influences on residential location decisions. In the 25- to 44-year age group, more than 50% of respondents said that the school district was very important.

Crime was the lead indicator of danger to respondents in the 1999 survey.[20] But homicides are not nearly so great a danger as traffic fatalities. Injuries from motor vehicle crashes and aggravated assaults are additional evidence for comparing the relative risks of crime and traffic. In 2000, there were 3 189 000 traffic injuries stemming from 2 070 000 injury crashes,[1(p2)] compared with 910 774 aggravated assaults,[2(p34)] a more than 3-to-1 ratio. It is reasonable to assume that locations of serious traffic injuries are closely associated with locations of traffic fatalities.

Three factors may account for the limited focus on traffic fatalities as a source of danger factored into residential location decisions. First, elements of traffic dangers—fatalities, injuries, accidents, and costs—are not publicized consistently for cities and counties. Whereas the Federal Bureau of Investigation's annual *Uniform Crime Reports* produce wide publicity about violent crime rates for hundreds of local government jurisdictions, no comparable report is publicized for traffic fatalities. Second, awareness by residents of traffic dangers in outlying areas does not mean that residents

will conclude their specific locations are dangerous. Traffic deaths do not accumulate near most residences; rather, their locations are strung along numerous roads and highways so that their connection to residential locations may be obscure. Third, traffic fatalities and injuries are accidental, lacking a deliberate perpetrator, so that personal care and skill alone may seem an adequate defense against them. The flaw in this belief is revealed in the fact that 56% of fatal crashes (21 052 of 37 409) occurred in single-vehicle accidents in 2000; 56% of the fatal single-vehicle crashes (11 696 of 21 052) involved the vehicle leaving the road.[1(p49)]

How to comprehend the risk associated with such high rates of violent traffic deaths? By comparing the rates of traffic fatalities to 2 emotional periods and settings for violent death—the October 2002 sniper killings in the Washington, DC, metropolitan area and the 2003 war in Iraq. Ten people died in the Washington, DC, sniper attacks during a 3-week period.[21] Applying a national average traffic death rate of about 42 000[3(p4)] to a metropolitan area of 5 million (such as Washington, DC) would produce about 40 deaths during a typical 3-week period. The deliberate nature of the sniper shootings was crucial to the fear and panic that affected residents. But the actual statistical risk of being killed by the sniper was far less than that for daily travelers in motor vehicles in the United States. In the second setting, the 2003 war in Iraq, 138 soldiers died through April 30, when the main war ended,[22] roughly equivalent to 1 day's worth of traffic deaths in the United States (about 115 deaths).

Crime involves feelings of greater vulnerability than does traveling in motor vehicles. Crime is purposeful, not accidental. Proximity to potential perpetrators, therefore, is feared. Potential locations of crime are more likely to be discussed. Often, fears are associated with stereotypes, especially when residential location decisions are made regarding a move to a metropolitan area from outside it, such as that portraying central cities dangerous and suburbs safe.[23] This common perception was captured by a nonrandom survey conducted in 2002 by the *Atlanta Journal–Constitution,* which asked "which area do you consider safest?" Nearly half of the respondents—46%—said rural, 21% said city, and 33% said suburbs.[24]

If perceptions of motor vehicle accident dangers are to increase substantially, improved research must be disseminated effectively. Reports on the conditions analyzed here should be repeated for the more than 300 metropolitan areas in the United States. Multiyear reports on traffic fatalities by central cities and metropolitan counties should be distributed annually by the NHTSA. Additional information should include risks for vehicle occupants who wear seat belts and who do not drink and drive.

Settlement patterns contribute to traffic dangers. Land use controls that establish clean edges around metropolitan areas, rather than extensive sprawl along narrow exurban roads, can reduce the dangers of leaving home. With more than 80% of daily trips occurring for purposes other than commuting to work, mixed-use settings for shopping, entertainment, school, and civic gatherings also are needed. A lower danger of leaving home can be achieved by less motor vehicle driving and more walking, biking, and public transportation, as well as more prevention related to motor vehicle features, driver and passenger behaviors, and road configurations. ■

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References

1. National Highway Traffic Safety Administration. *Traffic Safety Facts 2000: A Compilation of Motor Vehicle Crash Data From the Fatality Analysis Reporting System and the General Estimates System.* Washington, DC: US Dept of Transportation, National Highway Traffic Safety Administration; 2001.

2. Federal Bureau of Investigation. *Crime in the United States 2000: Uniform Crime Reports.* Washington, DC: US Dept of Justice, Federal Bureau of Investigation; 2001.

3. National Highway Traffic Safety Administration, National Center for Statistics and Analysis. *Motor Vehicle Traffic Crash Fatality and Injury Estimates: 2002 Early Assessment.* Washington, DC: US Dept of Transportation, National Highway Traffic Safety Administration; May 2003. Technical report DOT HS 809 586.

4. Federal Bureau of Investigation. *Crime in the United States 2001: Uniform Crime Reports.* Washington, DC: US Dept of Justice, Federal Bureau of Investigation; 2002.

5. Nelson A. Characterizing exurbia. *J Plann Lit.* 1992;6:350–368.

6. Texas Dept of Public Safety crime reports Web site. Available at: http://www.txdps.state.tx.us/crimereports. Accessed June 7, 2003.

7. Minnesota Dept of Public Safety, Bureau of Criminal Apprehension Web site. Available at: http://www.dps.state.mn.us/bca. Accessed June 7, 2003.

8. New Jersey State Police Web site. Available at: http://www.njsp.org. Accessed June 7, 2003.

9. Pennsylvania State Police Web site. Available at: http://www.psp.state.pa.us. Accessed June 7, 2003.

10. National Center for Statistics and Analysis. Fatality Analysis Reporting System (FARS) Web-Based Encyclopedia. Available at: http://www-fars.nhtsa.dot.gov. Accessed June 7, 2003.

11. Wisconsin Dept of Transportation Web site. Available at: http://www.dot.state.wi.us. Accessed June 7, 2003.

12. Minnesota Dept of Public Safety, Office of Traffic Safety Web site. Available at: http://www.dps.state.mn.us/ots. Accessed June 7, 2003.

13. US Census Bureau. *Census 2000 Summary File 1 (SF 1)* [detailed tables]. Available at: http://factfinder.census.gov. Accessed June 7, 2003.

14. US Census Bureau. *1990 Summary File 1 (STF 1)* [detailed tables]. Available at: http://factfinder.census.gov. Accessed June 7, 2003.

15. Virginia Dept of Motor Vehicles. *Virginia Traffic Crash Facts.* Richmond: Virginia Dept of Motor Vehicles; 1989–1998.

16. Uniform Crime Reporting Section. *Crime in Virginia.* Richmond, Va: Dept of State Police; 1989–1998.

17. Lucy WH, Rabalais R. Traffic fatalities and homicides by strangers: danger of leaving home in cities, inner suburbs, and outer suburbs. April 29, 2002. Available at: http://arch.virginia.edu/exurbia/death-in-exurbia.pdf. Accessed June 7, 2003.

18. Davis JS, Nelson AC, Dueker KJ. The new 'burbs: the exurbs and their implications for planning policy. *J Am Plann Assoc.* 1994;60(1):45–59.

19. Ewing R, Pendall R, Chen D. *Measuring Sprawl and Its Impact.* Washington, DC: Smart Growth America; 2002.

20. Myers D, Gearin E. Current preferences and future demand for denser residential environments. *Housing Policy Debate.* 2001;12(4):633–659.

21. Mosk M. Moose quits as chief in ethics flap. *The Washington Post.* June 19, 2003:A01.

22. Shanker T, Sanger DE. Bush addresses dangers faced by GIs in Iraq. *The New York Times.* June 22, 2003:A1.

23. Spain D. Why higher income households move to central cities. *J Urban Aff.* 1989;11:283–299.

24. Poe J. Fatality risk rated highest in exurbs: closer-in areas safer, study says. *Atlanta Journal–Constitution.* June 17, 2002:E1.

Prevalence of School Policies, Programs, and Facilities That Promote a Healthy Physical School Environment

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Objectives. We examined the extent to which schools in the United States have health-promoting policies, programs, and facilities.

Methods. We analyzed data from the School Health Policies and Programs Study 2000.

Results. We found that public schools (vs private and Catholic schools), urban schools (vs rural and suburban schools), and schools with larger enrollments (vs smaller schools) had more health-promoting policies, programs, and facilities in place. On average, middle schools had 11.0 and middle/junior and high schools had 10.4 out of a possible 18 policies, programs, and facilities.

Conclusions. Although some schools had many healthy physical environment features, room for improvement exists. Resources are available to help schools improve their health-promoting policies, programs, and facilities. (*Am J Public Health.* 2003;93:1570–1575)

The physical environment in schools is receiving increased national attention. Several federal efforts to improve school environments have been implemented during the past 5 years. In 1997, President Clinton created the Task Force on Environmental Health Risks and Safety Risks to Children.[1] On April 18, 2003, President Bush signed an executive order to extend the work of the task force through 2005.[2] Cochaired by the administrator of the Environmental Protection Agency and the secretary of the Department of Health and Human Services, the task force is charged with identifying and developing federal strategies to protect children from environmental health threats.[1]

In October 2001, the task force created a Schools Workgroup to explore ways for federal departments and agencies to expand cooperation to improve school environmental health. The Schools Workgroup's goals are to improve children's health and school performance by making existing and new schools healthier places to learn, and to ease the burden on underfunded and overextended school districts and schools by improving coordination and collaboration among federal, state, and local programs.

This improved coordination and collaboration comes at a critical time for schools. The average child spends about 1300 hours in a school building each year; teachers and other employees spend even more time.[3] Today, the average school building is about 42 years old; more than 75% of America's schools were built before 1970.[4]

More than 45 million elementary and secondary students attend approximately 86 000 public schools in the United States.[5] The number of students in kindergarten through twelfth grade is projected to reach 54.2 million by 2009.[6] It is estimated that 6000 new schools will be needed by 2007 to accommodate increasing enrollments, and thousands more schools will be needed later.[7]

Unfortunately, about one third of schools, affecting about 14 million students, report needing extensive repair or replacement of 1 or more buildings.[8] About one half of schools report at least 1 "unsatisfactory environmental condition," such as poor ventilation, heating or lighting problems, or poor physical security.[8] These unsatisfactory environmental conditions are most often reported in urban schools, in schools with a high minority student enrollment, and in schools with a high percentage of low-income students.[9–11]

Decisions about where a school is built, how the building is designed, how the school is maintained, and what school policies and programs are implemented have important implications for the health and learning potential of children who spend time in the school. *Healthy People 2010* sets public health objectives for the nation to achieve by 2010.[12] Objective 8-20 specifically focuses on the school setting: "Increase the proportion of the Nation's primary and secondary schools that have official school policies ensuring the safety of students and staff from environmental hazards, such as chemicals in special classrooms, poor indoor air quality, asbestos, and exposure to pesticides."[12(p8-26)]

No study has comprehensively assessed the extent to which schools have health-promoting policies, programs, and facilities. However, the School Health Policies and Programs Study (SHPPS) 2000, conducted by the Centers for Disease Control and Prevention (CDC), provided data on physical and tangible features of school buildings and on policies that promote a physically and socially healthy built environment. In this study, we analyzed data from SHPPS 2000 to examine the extent to which schools in the United States have health-promoting policies, programs, and facilities.

METHODS

SHPPS 2000 assessed programs and policies on 8 components of the school health program at the state, district, and school levels. This report summarizes selected school-level data only; state- and district-level results are reported elsewhere.[13] School-level data were collected from a nationally representative sample of public and private elementary, middle/junior high, and senior high schools.

Questionnaire development took 2 years and included extensive literature reviews; expert panel meetings; reviews by representatives of federal agencies and national organizations; cognitive testing with school, district, and state education agency volunteers; and a formal field test of 4 questionnaires. In conjunction with the administration of SHPPS

2000, a test–retest substudy was designed and implemented to assess data quality.[14] SHPPS 2000 data were generally of high quality. Among the 99 categorical and ordinal questions selected from across all school-level questionnaires, 5% exhibited almost perfect reliability ($\kappa > 80\%$), 41% exhibited substantial reliability ($\kappa > 60\%$), 42% exhibited moderate reliability ($\kappa > 40\%$), and 11% exhibited poor reliability ($\kappa \leq 40\%$).[14]

The SHPPS 2000 questionnaires relevant to this study assessed physical education and activity, health services, mental health and social services, food service, and school policy and environment. These data were then linked with extant data on school characteristics from the Quality Education Data (QED) database.[15] QED variables included in this analysis were school type (public, private, or Catholic), urbanicity (urban, suburban, or rural), school enrollment size, discretionary per-pupil expenditure, percentage of White students, and percentage of college-bound students.

School-level data were collected by computer-assisted personal interviews. During recruitment, the principal or other school-level contact designated, for each component, a faculty or staff respondent who had primary responsibility for, or was the most knowledgeable about, that component. All interviews were completed between January and June 2000. Smith et al. have provided a detailed description of SHPPS 2000 methodology.[16]

Response rates for the interviews varied by school health program component. The response rate for physical education and activity was 69% (n=921); for health services, 71% (n=938); for mental health and social services, 67% (n=876); for food service, 70% (n=841); and for school policy and environment, 70% (n=927). We compared the characteristics of responding schools (schools that completed at least 1 of the 7 SHPPS 2000 school-level interviews) with those of nonresponding schools (schools that did not complete any interviews). Participation varied by school type ($\chi^2=103.3$; $P<.01$). Of the schools that responded, 83% were public, 11% were private, and 7% were Catholic. Of the schools that did not respond, 53% were public, 37% were private, and 9% were Catholic. Responding schools also were significantly larger (mean enrollment: 550 in responding schools vs 404 in nonresponding schools; $t=4.5$; $P<.01$) and had a higher percentage of White students enrolled (56% in responding schools vs 32% in nonresponding schools; $t=10.5$; $P<.01$). Participation did not vary by school level (elementary, middle/junior high, or senior high), urbanicity, percentage of college-bound students, or discretionary per-pupil expenditure.

All analyses used SUDAAN (Research Triangle Institute, Research Triangle Park, NC) to account for the complex sample design in SHPPS 2000; results are based on weighted data. The selection of policies, programs, and facilities for this analysis was based primarily on CDC guidelines.[17–20] To determine whether the prevalence of each of these policies, programs, and facilities varied by school level, we conducted χ^2 analyses (the significance level was set at $P<.01$ to account for multiple comparisons).

The following policy, program, and facility variables were used to examine unintentional injury and violence prevention: (1) requires uniforms or dress code (students must wear school uniforms or there is a dress code), (2) uses communication devices (during the school day, the school staff uses communication devices, such as cell phones, 2-way radios, walkie-talkies, or intercoms), (3) designates a weapons-free school zone (the school posts signs marking a specified distance from school grounds in which weapons are not allowed), (4) participates in a "safe passages" program (school has safe routes to school so students do not have to go through dangerous areas), and (5) has performed all appropriate inspection and maintenance of facilities and equipment (school buses and other vehicles; playground facilities and equipment; indoor and outdoor athletic facilities and equipment; environmental hazards, such as asbestos, pesticides, and laboratory chemicals; school kitchen facilities and equipment; special classrooms, such as chemistry labs and workshops; smoke detectors; fire extinguishers; and indoor and outdoor lighting) and uses the Consumer Product Safety Commission checklist for playground safety (safety checklist and equipment guidelines).[21]

Variables used to examine tobacco, alcohol, and other drug use policies, programs, and facilities included (1) prohibits all tobacco use (by students, all school staff, and visitors on school property, in school vehicles, and at school-sponsored functions away from school property), (2) prohibits tobacco advertising (in the school building, on school grounds, on school buses, in school publications, and through sponsorship of school events), (3) designates a tobacco-free school zone (school posts signs marking a tobacco-free school zone), and (4) designates a drug-free school zone (school posts signs marking a drug-free school zone).

Variables used to examine nutrition and dietary policies, programs, and facilities included (1) does not have "junk food" (food that provides calories primarily through fats or added sugars and has minimal amounts of vitamins and minerals) available before or during school hours, (2) does not have a soft drink contract or does not allow soft drink advertising (in the school building, on school grounds, or on school buses), (3) does not promote junk food (school does not promote consumption of candy, meals from fast-food restaurants, or soft drinks through posters or displays; advertisements on textbook covers, on school food service menus, or in the school newsletter, newspaper, or other publication; coupons for free or reduced prices on those products; or sponsorship of school events), (4) has a cafeteria, and (5) operates cafeteria at or below capacity at peak mealtimes (100% full or less).

Finally, variables used to examine health services, mental health and social services, and physical activity policies, programs, and facilities included (1) has a sickroom (nurse's office or other area reserved for providing standard health services), (2) has supplies for universal precautions (in all classrooms, in gymnasiums, on playgrounds, on playing fields, and on school buses or other vehicles used to transport students), (3) has a private room for providing mental health and social services, and (4) has any indoor or outdoor facilities for physical education.

Except for the variable assessing compliance with playground safety guidelines (because that question was asked only of elementary schools), the variables measuring

school health policies, programs, and facilities were combined in an index. The index provides a count of the policies, programs, and facilities in place; each school, therefore, received a score between 0 and 18. This score, referred to as the school's "policy, program, and facility" score, was used as the dependent variable in regression models.

Preliminary analyses indicated that pairwise correlations among the independent variables (the QED variables) were all less than or equal to .27; thus, we included all independent variables in the regression model. The full model was overspecified. Although pairwise correlations analysis will not diagnose collinearity between a given independent variable and a linear combination of a subset of other independent variables, more robust multicollinearity diagnostics were not possible. Because of this limitation, it was necessary to run separate models, each with independent variables that were conceptually related.

The first regression model included the following independent variables: school level (elementary vs middle/junior high vs senior high), school type (public vs private vs Catholic), urbanicity (urban vs suburban vs rural), and school enrollment size (included as a continuous variable). The second model included school level plus 2 continuous independent variables: discretionary per-pupil expenditure and percentage of White students in the school. Because the percentage of college-bound students was assessed only at the high school level, the third model—which included discretionary per-pupil expenditure, percentage of White students, and percentage of college-bound students as independent continuous variables—was run for high schools only.

RESULTS

The percentage of schools that inspected and provided appropriate maintenance to their equipment and facilities is shown in Table 1. More than 80% of schools performed each type of inspection and maintenance, with most types being performed by more than 95% of schools. Because of the lack of variability among these types of inspection and maintenance, they were combined into a single variable that indicated whether the school performed all of these types of inspection and maintenance.

TABLE 1—Percentage of Schools That Inspected and Provided Appropriate Maintenance to Equipment and Facilities During the 12 Months Preceding the Study: School Health Policies and Programs Study, 2000

Type of Policy	Schools (%)
Fire extinguishers	99.3
Inspection or maintenance of halls, stairs, and regular classrooms	96.6
Inspection or maintenance of indoor athletic facilities and equipment	95.5
Inspection or maintenance of kitchen facilities and equipment	96.6
Inspection or maintenance of outdoor athletic facilities and equipment	94.8
Inspection or maintenance of playground facilities or equipment[a]	94.8
Inspection or maintenance of school buses or other vehicles used to transport students	98.4
Inspection or maintenance of special classroom areas (e.g., chemistry labs, workshops, art rooms)	80.8
Lighting inside of the buildings	97.5
Lighting outside of the buildings	94.6
Protection of students and staff from environmental hazards	94.4
Smoke detectors	85.2

[a]Among elementary and middle/junior high schools only.

For each school level, the prevalence of each policy, program, and facility related to a healthy physical school environment, including the combined inspection and maintenance variable just described, is shown in Table 2. Although many of the policies, programs, and facilities were equally likely to be in place at all school levels, the analysis revealed a few exceptions. For example, senior high schools were the most likely to have performed appropriate inspections and maintenance in the 12 months preceding the study. Middle/junior high schools were more likely than elementary schools to require uniforms or a dress code. In addition, elementary schools were the most likely, and senior high schools the least likely, to limit the availability of junk food to students through vending machines, canteens, and school stores. Similarly, elementary schools were the most likely, and senior high schools the least likely, to prohibit soft drink advertising or to not have a soft drink contract.

The distribution of policy, program, and facility scores for each school level is shown in Table 3. Elementary schools had a mean of 11.0 (95% confidence interval [CI]=10.6, 11.4) policies, programs, and facilities in place; middle/junior high schools had a mean of 10.4 (95% CI=10.0, 10.8); and senior high schools had a mean of 10.4 (95% CI=10.1, 10.7). No school had all 18 of these policies, programs, and facilities in place, and fewer than 10% of schools at any level had 15 or more in place.

Regression analysis indicated that school level was significantly associated with the policy, program, and facility score, with elementary schools having significantly higher scores than senior high schools ($\beta=0.6$; $P=.02$). On the basis of this finding, school level was included as a control variable in subsequent analyses. The first regression model (including school type, urbanicity, and school size as independent variables) revealed that the policy, program, and facility score was significantly associated with each of the independent variables. Specifically, Catholic schools ($\beta=-2.2$; $P<.0001$; mean score=9.3) and private schools ($\beta=-3.9$; $P<.0001$; mean score=7.4) had significantly lower scores than did public schools (mean score=11.7). In addition, rural schools ($\beta=-0.6$; $P=.05$; mean score=10.5) and suburban schools ($\beta=-0.4$; $P=.04$; mean score=10.5) had significantly lower scores than did urban schools (mean score=11.2). School size was positively associated with score, indicating that the larger the school, the higher its score ($\beta=.001$; $P<.001$).

The second and third regression analyses did not reveal any statistically significant associations among policy, program, and facility score and the percentage of White students, the school's discretionary per-pupil expenditure, or, among high schools, the percentage of college-bound students (all $P\geq.2$).

TABLE 2—Percentage of Elementary, Middle/Junior High, and Senior High Schools With Policies, Programs, and Facilities Related to a Healthy Physical School Environment: School Health Policies and Programs Study, 2000

Policies, Programs, and Facilities	Elementary Schools (%)	Middle/Junior High Schools (%)	Senior High Schools (%)	χ^2
Has performed all appropriate inspection and maintenance of facilities and equipment[a]	35.7	40.3	56.8	24.9**
Requires uniforms or dress code	82.1	93.5	88.3	19.6**
Uses communication devices	80.7	78.0	80.1	0.6
Designates a weapons-free school zone	24.4	21.2	25.8	2.4
Has a safe passages program	16.4	13.0	8.1	10.9*
Prohibits all tobacco use	47.8	41.9	49.4	3.4
Prohibits tobacco advertising	91.3	91.1	91.2	0.01
Designates a tobacco-free school zone	43.2	38.6	46.5	3.3
Designates a drug-free school zone	53.3	48.1	49.4	1.7
Uses Consumer Product Safety Commission checklist for playground safety[b]	47.8	...	...	...
Does not have junk food available before or during school hours	60.9	34.4	5.7	180.8**
Does not have a soft drink contract or does not allow soft drink advertising	88.2	77.2	56.4	72.2**
Does not promote junk food	66.2	65.8	59.3	3.8
Has a cafeteria	88.6	91.7	93.6	3.3
Cafeteria operates at or below capacity at peak mealtimes	98.5	96.0	92.6	11.9*
Has a sickroom	84.8	75.4	78.6	8.6*
Has supplies for universal precautions	36.9	34.6	36.8	0.5
Has a private room for providing mental health and social services	90.7	88.7	96.2	12.1*
Has any indoor or outdoor facilities for physical education	100.0	100.0	99.6	1.0

[a]See Table 1 for types of inspection and maintenance included in this variable.
[b]Not included in index.
*$P < .01$; **$P < .0001$. P values are 2-tailed.

TABLE 3—Distribution of Policy, Program, and Facility Scores Related to a Healthy Physical School Environment, by School Level: School Health Policies and Programs Study, 2000

Policy, Program, and Facility Score[a]	Elementary Schools (%)	Middle/Junior High Schools (%)	Senior High Schools (%)
1	0.5	0.6	0.0
2	1.0	0.6	0.7
3	0.4	0.0	0.6
4	1.3	3.2	0.7
5	3.8	1.8	1.6
6	4.9	3.0	2.1
7	2.3	6.5	5.4
8	7.2	7.3	11.0
9	6.9	13.8	15.5
10	7.9	11.0	9.9
11	11.2	12.7	18.6
12	15.6	15.7	10.3
13	17.9	11.2	14.4
14	10.3	7.8	6.1
15	5.0	3.4	1.8
16	2.3	1.4	1.4
17	1.6	0.0	0.0
18	0.0	0.0	0.0

[a]The policies, programs, and facilities examined in this study (see Table 2) were combined into an index counting the number of policies and programs in place. Each school received a policy and program score between 0 and 18.

DISCUSSION

The policies and programs that a school chooses to adopt and the physical environment it maintains are important aspects of the school environment that promote health, safety, and learning among students. This study examined various physical features of school buildings as well as policies and programs that influence the physical nature of the school in a variety of areas, including violence and unintentional injury; alcohol, tobacco, and other drug use; nutrition and dietary behaviors; health services; mental health and social services; and physical activity and fitness. Whereas SHPPS 2000 examined other features of the physical school environment, the policies, programs, and facilities examined in this analysis were limited to those recommended in literature such as the CDC guidelines for school health programs.

For example, the CDC *School Health Guidelines to Prevent Unintentional Injuries and Violence*[17] advocates conducting regular safety and hazard assessments of the building facility and equipment, and, for elementary schools, using the Consumer Product Safety Commission playground safety checklist,[21] which can be used to ensure that playground equipment is safely maintained. Only 57% of senior high schools and less than 50% of elementary and middle/junior high schools reported performing all appropriate inspection and maintenance of facilities and equipment. Fewer than one half of elementary schools reported using the Consumer Product Safety Commission playground safety checklist. SHPPS 2000 did not examine the reasons for deficits in inspections and maintenance; however, it may be that tight school budgets are contributing to understaffing or inadequate repair budgets. These data are not surprising, given that the US General Accounting Office found that about one third of schools reported needing extensive repair or replacement of 1 or more buildings.[8]

The CDC *Guidelines for School Health Programs to Prevent Tobacco Use and Addiction*

supports the prohibition of tobacco product use and advertising on school grounds.[18] Such policies not only prevent exposure of students and staff to environmental tobacco smoke but also create an environment that supports nonsmoking and a student's decision not to smoke.[18] By analogy, drug-free school zones were included in this analysis as well. Although 9 of 10 schools prohibit tobacco advertising, far fewer schools prohibit all tobacco use among students, teachers, staff, and visitors and specifically designate a tobacco-free and drug-free school zone.

This analysis found that most schools had a cafeteria that could accommodate students during mealtimes; however, far fewer schools, especially senior high schools (6%), reported that junk food was unavailable to students during school hours. These data are relevant to national concern regarding the increasing obesity epidemic among youth. Results from the 1999–2000 National Health and Nutrition Examination Survey indicate that an estimated 15% of children and adolescents aged 6 to 19 years are overweight.[22] School-based environmental strategies to promote physical activity and healthy eating are important in addressing this problem.[23] As described in the CDC *Guidelines for School and Community Programs to Promote Lifelong Physical Activity Among Young People*[19] and *Guidelines for School Health Programs to Promote Lifelong Healthy Eating,*[20] school cafeterias that allow children to eat in comfortable surroundings, school policies that promote healthy eating and provide healthy choices, and opportunities for physical activity during the school day are critical environmental elements for addressing obesity among youth.[19,20,23,24]

Most schools reported that they had a sickroom for providing standard health services for students and a private room for providing mental health and social services. However, only about one-third of schools reported that they had supplies for universal precautions in all classrooms, in gymnasiums, on playgrounds, on playing fields, and on school buses or other vehicles used to transport students. Research has shown that whereas most (77%) schools have a part- or full-time school nurse who provides health services to students at the school, those school nurses are present for only an average of 22 hours per week.[25] Consequently, it is likely that some student injuries will occur when a school nurse is unavailable. If supplies for universal precautions were widely available to teachers and staff, they would be better able to protect themselves and students in the event of an emergency.

Other research suggests that urban schools, schools with a high minority student enrollment, and schools with a high percentage of low-income students are more likely to experience unsatisfactory school environmental conditions, such as poor ventilation, heating or lighting problems, or inadequate physical security.[8–11] Our analysis found contrary results for the particular environmental variables investigated in our study; that is, urban schools were implementing more environmental policies and programs and had more facilities. In addition, the percentage of White students, the school's discretionary per-pupil expenditure, and, among high schools, the percentage of college-bound students were not indicative of a more health-promoting physical environment as measured in this study. This analysis also found that elementary schools were more likely than senior high schools, public schools more likely than private and Catholic schools, and larger schools (i.e., those with higher enrollment) more likely than smaller schools to adopt more policies and programs or to have these facilities. However, these data do not provide insight into the reasons for these differences. It is not clear, for example, whether schools with lower policy, program, and facility scores fail to perceive a need for these school features, have less oversight, or lack the financial or human resources to implement the policies and programs.

This study has at least 3 important limitations. First, SHPPS 2000 was not designed to investigate fully all aspects of the physical school environment, and some important data on this topic are absent. For example, recent reports suggest that daylighting in schools[26] and indoor air quality issues[27] are linked to school attendance and student performance, but these variables were not examined in SHPPS 2000. Second, the school demographic variables we used might not fully capture the characteristics of a school. For example, the percentage of college-bound students is just 1 measure of the level of student achievement in the school. Third, these data are cross-sectional and do not allow us to infer causality.

Although schools are implementing some important school building policies and programs and have important facilities in place, room for improvement exists. On average, elementary schools had 11.0 and middle/junior and senior high schools had 10.4 out of a possible 18 policies, programs, and facilities examined in this study. The CDC's school health guidelines provide guidance to personnel and policymakers at the school, district, state, and national levels on unintentional injuries and violence,[17] tobacco use and addiction,[18] physical activity,[19] and healthy eating.[20] These guidelines include a school environment component. To help put the recommendations included in these guidelines into action, the CDC also developed the School Health Index, a self-assessment and planning guide that enables schools to identify the strengths and weaknesses of their health promotion policies and programs; develop an action plan for improving student health; and involve teachers, parents, students, and the community in improving school services.[28] The results of the analyses presented in this article suggest that many schools could benefit from these resources. ■

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Contributors

S. Everett Jones and N.D. Brener planned the analysis and wrote the article. N.D. Brener supervised data analysis. T. McManus conducted the data analysis.

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References

1. Executive Order 13045: Protection of children from environmental health risks and safety risks. 62 *Federal Register* 19 885 (1997).

2. Amendments to Executive Order 13045, protection of children from environmental health risks and safety risks, 68 *Federal Register* 19 931 (2003).

3. Day DR. *Environmental Law: Fundamentals for Schools.* Alexandria, Va: National School Boards Association; 1995.

4. Lyons JB. *IssueTrak: Do School Facilities Really Impact a Child's Education?* Scottsdale, Ariz: Council of Educational Facility Planners International; November 2001.

5. US General Accounting Office. *School Facilities: Construction Expenditures Have Grown Significantly in Recent Years.* Washington, DC: US General Accounting Office; 2000. GAO/HEHS-00-41.

6. US Department of Education. *A Back to School Special Report on the Baby Boom Echo: No End in Sight.* Washington, DC: US Dept of Education; August 19, 1999. Available at: http://www.ed.gov/pubs/bbech099. Accessed June 7, 2003.

7. Sustainable Buildings Industry Council. *High Performance School Buildings: Resource and Strategy Guide.* Washington, DC: Sustainable Buildings Industry Council; 2001.

8. US General Accounting Office. *School Facilities: Condition of America's Schools.* Washington, DC: US General Accounting Office; 1995. GAO/HEHS-95-61.

9. US General Accounting Office. *School Facilities: America's Schools Report Differing Conditions.* Washington, DC: US General Accounting Office; 1996. GAO/HEHS-96-103.

10. American Public Health Association. *Creating Healthier School Facilities.* Washington, DC: American Public Health Association; 2000. Policy Number 200010.

11. School Siting Committee, Child Proofing Our Communities Campaign. *Creating Safe Learning Zones: Invisible Threats, Visible Actions.* Falls Church, Va: Center for Health, Environment and Justice; January 2002. Available at: http://www.childproofing.org/cslzindex.html. Accessed June 7, 2003.

12. US Department of Health and Human Services. *Healthy People 2010.* Conference ed. 2 vols. Washington, DC: US Dept of Health and Human Services; 2000.

13. School Health Policies and Programs Study 2000: a summary report. *J Sch Health.* 2001;71:251–350.

14. Brener ND, Kann L, Smith TK. Reliability and validity of the School Health Policies and Programs Study 2000 questionnaires. *J Sch Health.* 2003;73:29–37.

15. Quality Education Data National Education Database. Denver, Colo: Quality Education Data; 1998. Available at: http://www.qeddata.com. Accessed June 7, 2003.

16. Smith TK, Brener ND, Kann L, Kinchen SA, McManus T, Thorne J. Methodology for the School Health Policies and Programs Study 2000. *J Sch Health.* 2001;71:260–265.

17. Centers for Disease Control and Prevention. School health guidelines to prevent unintentional injuries and violence. *MMWR Morb Mortal Wkly Rep.* 2001;50(RR-22):1–73.

18. Centers for Disease Control and Prevention. Guidelines for school health programs to prevent tobacco use and addiction. *MMWR Morb Mortal Wkly Rep.* 1994;43(RR-2):1–18.

19. Centers for Disease Control and Prevention. Guidelines for school and community programs to promote lifelong physical activity among young people. *MMWR Morb Mortal Wkly Rep.* 1997;46(RR-6):1–36.

20. Centers for Disease Control and Prevention. Guidelines for school health programs to promote lifelong healthy eating. *MMWR Morb Mortal Wkly Rep.* 1996;45(RR-9):1–41.

21. US Consumer Product Safety Commission. Washington, DC: US Consumer Product Safety Commission, Office of Information and Public Affairs; 1997. Number 325.

22. Centers for Disease Control and Prevention. *Prevalence of Overweight Among Children and Adolescents: United States, 1999–2000.* Hyattsville, Md: Centers for Disease Control and Prevention, National Center for Health Statistics. Available at: http://www.cdc.gov/nchs/products/pubs/pubd/hestats/overwght99.htm. Accessed June 7, 2003.

23. Wechsler H, Devereaux RS, Davis M, Collins J. Using the school environment to promote physical activity and healthy eating. *Prev Med.* 2000; 31:S121–S137.

24. Hannan P, French SA, Story M, Fulkerson JA. A pricing strategy to promote sales of lower fat foods in high school cafeterias: acceptability and sensitivity analysis. *Am J Health Promot.* 2002;17:1–6, 11.

25. Brener ND, Burstein GR, DuShaw ML, Vernon ME, Wheeler L, Robinson J. Health services: results from the School Health Policies and Programs Study 2000. *J Sch Health.* 2001;71:294–304.

26. Heschong Mahone Group. *Daylighting in Schools: An Investigation Into the Relationship Between Daylighting and Human Performance.* San Francisco, Calif: Pacific Gas & Electric Co; 1999.

27. US Environmental Protection Agency. *IAQ Tools for Schools: IAQ Backgrounder.* Washington, DC: US Environmental Protection Agency; 2000. Available at: http://www.epa.gov/iaq/schools/tfs/iaqback.pdf. Document Number 402-C-00-002. Accessed June 7, 2003.

28. Centers for Disease Control and Prevention. *SHI: School Health Index for Physical Activity, Healthy Eating and a Tobacco-Free Lifestyle. A Self-Assessment and Planning Guide.* Atlanta, Ga: Centers for Disease Control and Prevention; 2002. Available at: http://www.cdc.gov/nccdphp/dash/SHI/index.htm. Accessed June 7, 2003.

Moving to Opportunity: an Experimental Study of Neighborhood Effects on Mental Health

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Objectives. The health consequences of neighborhood poverty are a public health problem. Data were obtained to examine links between neighborhood residence and mental health outcomes.

Methods. Moving to Opportunity was a randomized, controlled trial in which families from public housing in high-poverty neighborhoods were moved into private housing in near-poor or nonpoor neighborhoods, with a subset remaining in public housing. At the 3-year follow-up of the New York site, 550 families were reinterviewed.

Results. Parents who moved to low-poverty neighborhoods reported significantly less distress than parents who remained in high-poverty neighborhoods. Boys who moved to less poor neighborhoods reported significantly fewer anxious/depressive and dependency problems than did boys who stayed in public housing.

Conclusions. This study provides experimental evidence of neighborhood income effects on mental health. (*Am J Public Health.* 2003;93:1576–1582)

During the past few decades, increasing attention has been drawn to the neighborhoods in which families with children live and interact. Policymakers' concerns have focused on large urban centers where high concentrations of poor families reside; many of these families dwell in public housing.[1,2] In addition to poverty, these neighborhoods have been marked by high unemployment rates, large numbers of families receiving welfare, and pervasive crime and violence. However, no experimental evidence exists for links between neighborhood residence and health and behavior, because families have some choice, albeit limited in the case of low-income families, about the neighborhoods in which they live (resulting in problems of selection bias[3–5]).

In 1994, the US Department of Housing and Urban Development (HUD) launched a novel social experiment, the Moving to Opportunity for Fair Housing Demonstration (MTO), in 5 sites (Baltimore, Boston, Chicago, Los Angeles, and New York City). The MTO is a randomized housing mobility experiment in which families with children who lived in public housing in high-poverty neighborhoods were given the opportunity to move to less poor neighborhoods. This program was motivated by evidence from existing housing relocation programs that rental assistance combined with housing counseling can help low-income families move to private housing in low-minority-concentration or low-poverty neighborhoods and possibly increase their educational and employment opportunities.[6,7] These studies did not, however, use randomized designs or consider noneconomic outcomes.

Beyond possible economic benefits, residential mobility programs such as MTO are likely to have consequences for morbidity. Evidence from nonexperimental studies indicates that residence in a low-income neighborhood is associated with unfavorable physical and mental health.[3] Thus, moving from a high-poverty neighborhood to a less poor neighborhood may improve health.

This study focused on the short-term impact of the MTO program in New York City. The consequences of moving from high-rise public housing in high-poverty neighborhoods to either private housing in similar neighborhoods or private housing in low-poverty neighborhoods for parents' and children's mental health were investigated. Outcomes were examined approximately 2 years after families who received vouchers had moved (3 years since baseline and random assignment).

METHODS

The selection of participants, design, and methods of the national MTO evaluation have been described in detail elsewhere[8,9] and are briefly summarized here.

Design and Description of MTO Program

The MTO is a housing relocation program in which families who resided in public housing or received project-based assistance under the Section 8 program and who had at least 1 child younger than 18 years were eligible to participate. Housing projects from which participants were recruited were located in census tracts with poverty rates in excess of 40%, as measured by the 1990 US Census. A randomized controlled design was used such that families who volunteered for the program were assigned to 1 of 3 groups: (1) the experimental, or treatment, group, whose members received Section 8 housing vouchers and special assistance to move only to low-poverty neighborhoods (<10% poor according to the 1990 US Census); (2) the comparison group, whose members received Section 8 housing vouchers under the regular, geographically unrestricted program (Section 8 group); or (3) the control group, whose members did not receive vouchers but continued to receive project-based assistance (in-place control group). The Section 8 program allocates vouchers for rent subsidies to purchase approved housing in the private market. The special assistance received by experimental families was provided by local nonprofit organizations and varied across sites. In general, these services entailed assisting families with finding units and overcoming obstacles to obtaining housing in low-poverty neighborhoods, as well as working with landlords unfamiliar with the Section 8 program or unaccustomed to renting to families from public housing. Random as-

signment was conducted by means of specially designed software for the MTO program; assignment to each condition was based on an expected treatment compliance (or take-up) rate of 25% at each site.

Families that volunteered for the program were more disadvantaged than their public housing counterparts who did not join MTO; MTO families were more likely than nonparticipating families to receive welfare and to be headed by women who were young and unemployed.[9]

Abt Associates Inc., under contract with HUD, conducted baseline interviews with heads of households from 1994 to 1999, before random assignment and relocation of movers. The structured interviews focused on demographic information, with limited data obtained for each household member, including children. HUD contracted different teams of researchers to conduct site-specific follow-up evaluations.[10]

TABLE 1—Baseline Parental and Family Characteristics by Treatment Group: MTO Demonstration, New York City, 1994–1999

	Experimental (n = 220)	Section 8 (n = 181)	In-Place Control (n = 149)	Total (n = 550)
Mean parental age, y (SD)	35.77 (10.13)	35.43 (9.13)	34.96 (9.67)	35.44 (9.67)
Sex, % female	91.3	96.1	92.6	93.2
Parental race/ethnicity, %				
African American	48.6	50.5	51.0	49.9
Latino/Latina	48.6	45.1	45.6	46.6
Other	2.8	4.4	3.4	3.5
Parent is high school graduate/GED, %	66.5	67.4	58.4	64.6
Parent is married, %	12.1	7.7	12.3	10.7
Parent is employed, %	22.3	26.6	28.1	25.3
Main reason want to move, %				
Better schools for children	16.8	18.6	18.6	17.9
Get away from drugs and gangs	49.5	48.5	53.6	50.3
Get bigger/better apartment	29.5	31.7	25.0	29.0
Other	4.2	1.2	2.9	2.8

Note. MTO = Moving to Opportunity for Fair Housing Demonstration; GED = graduate equivalency diploma. Descriptive statistics are weighted by date of random assignment because the assignment ratio for the 3 groups changed throughout the randomization period. No significant group differences were found.

New York City MTO Evaluation

We report on a follow-up evaluation of the New York City MTO site (n=794). Three years after baseline interviews were completed, we hired field staff from Schulman, Ronca, and Bucuvalas, Inc. to conduct in-home follow-up interviews with primary caregivers and up to 2 randomly selected children per household (in sampling, priority was given to children who lived in the household at baseline and to children who were 3 years of age and older). For the small subset of families who had moved out of the metropolitan area, telephone interviews were conducted with a parent and 1 randomly selected child 11 years of age or older per household (n=14 families). The parents' interviews were administered in English or Spanish, and the children's interviews were administered in English only. Given the nature of the program, the interviewers were not blind to the group assignments of the participants. In total, 550 families were interviewed as part of this follow-up evaluation between 1998 and 2000, for a 69% response rate. In general, families that participated in the follow-up did not significantly differ from those that did not participate (not shown; data available from the authors).

Information was obtained on an average of approximately 1.5 children per household (n=806). On average, children were 10.72 (SD=4.15) years of age at follow-up (range 1.15–19.35).

Overall, 40% of families used the randomly assigned treatment (vouchers) they were offered to move to new neighborhoods (42% of the experimental group and 38% of the Section 8 group). Across all 5 sites, the compliance rate for the experimental group was 47% and for the Section 8 group was 60%, which was higher than the expected rate of 25%.[9]

Sample Description

Table 1 displays the groups' baseline parent and family characteristics. Overall, randomization yielded comparable experimental, Section 8, and control groups (all baseline differences among groups were insignificant). At the time of baseline interviews, the parents were in their mid-30s, and approximately two thirds had a high school degree or the equivalent. Approximately half of the sample was African American, and the remainder was Latino/Latina (a small number reported "other" for race/ethnicity). Most households were headed by unmarried parents, and in most cases, mothers were interviewed. When asked the primary reason for wanting to move from their current neighborhood, a majority of parents reported getting away from drugs and gangs (this sentiment was consistent with results at other MTO sites[9]).

This study focuses on 512 children who were 8 to 18 years of age at follow-up (mean=12.62, SD=2.74). The sample was split evenly by the sex of the children.

At follow-up, families resided in 170 census tracts, with an average of 3.24 (SD=5.48) families per neighborhood. Although it was still relatively low, clustering within neighborhoods was highest among in-place controls (mean=2.98, SD=3.32), followed by experimental (mean=2.37, SD=2.67) and then Section 8 (mean=1.87, SD=1.87) families.

Measures

The major outcome of interest at follow-up was mental health; all measures assessed subclinical problems and therefore did not permit diagnostic classifications but are known to be correlated with clinical status and receipt of psychosocial treatment.[11–14] We also consid-

ered neighborhood conditions and family economic well-being, because they were the primary targets of the MTO program.

Neighborhood Economic and Social Conditions. Characteristics of neighborhoods in which families resided at follow-up were assessed. Neighborhood demographic characteristics were measured by 1990 US Census data. Neighborhood physical and social disorder was measured by parental ratings of the size of problems (trash, graffiti, public drinking, public drug use or dealing, and abandoned buildings) in their neighborhoods from "not a big problem" (1) to "a big problem" (3); total mean scores were calculated, with higher scores reflecting greater disorder (range 1–3). Parents also reported level of satisfaction with their neighborhoods, rated from "very satisfied" (1) to "very dissatisfied" (5); we reverse coded scores, so higher scores represent greater satisfaction. Interviewer observations characterized the quality of the immediate external environment of respondents' homes; interviewers rated the condition of the housing and street and the presence of garbage and drugs/alcohol (M.B. Selner-O'Hagan, T. Leventhal, J. Brooks-Gunn, J.B. Bingenheimer, and F. Earls, 2002, unpublished data). All 4 items were coded dichotomously, and total raw scores were calculated (range 0–4). Higher scores signify lower-quality environments.

Parents' Mental Health. Depressive (Depressive Mood Inventory[11]) and distress or anxiety (Hopkins Symptom Checklist[12]) symptoms were assessed. For both scales, parents reported how often each symptom was present during the past month, on a 5-point scale from "not at all" (1) to "all of the time" (5). Total scores were calculated as mean item scores; higher scores indicate poorer health (range 1–5).

Children's Mental Health. Behavior problems were assessed with the Behavior Problems Index, a 28-item scale widely used in national health surveys.[13,14] Children reported how true each behavior was of them during the past 6 months, on a 3-point scale from "not true" (0) to "often true" (2); in keeping with past work,[14] the scores were recoded to reflect whether behavior was reported as either not true (0) or as sometimes or often true (1).[14] Subscale scores were calculated for anxious/depressive (e.g., unhappy, sad, or depressed; too fearful or anxious; range 0–5), dependency (e.g., need to be near adults; cry a lot; range 0–4), headstrong (e.g., argue a lot; strong/hot temper; range 0–5), and antisocial (e.g., lie and cheat; tease others a lot or cruel/mean to others; range 0–6) problems. Total raw scores were used as outcomes, with higher scores indicating more problems.

Family Economic Well-Being. These outcomes, reported by parents, include current parental employment status as well as welfare receipt and income for the past year. Reported household size was used to calculate per-person income.

Analytic Strategy

The purpose of all analyses was to compare (1) the experimental group and in-place controls and (2) the Section 8 group and in-place controls. Analysis of variance was employed to evaluate group differences in neighborhood socioeconomic conditions and quality. Overall group differences were tested and post hoc pairwise comparisons of differences were examined. All pairwise mean comparisons were Bonferroni-adjusted ($\alpha/3$). Ordinary least squares regression analyses, similar to those used for parental outcomes, were used to estimate the program's effects on parent-reported neighborhood disorder and satisfaction.

Regression was employed to evaluate the program's effects on parents' and children's mental health and family economic well-being according to randomization status, regardless of whether families complied with the assigned treatment (i.e., intention-to-treat [ITT] analyses); ordinary least squares regression was used for continuous outcomes and logistic regression for bivariate outcomes. All analyses included 2 indicator variables for the treatment status, 1 for the experimental group and another for the Section 8 group; the in-place control group served as the referent. Analyses of parents controlled for the following baseline characteristics: sex, race/ethnicity, age, education, employment status, marital status, and number of children in the household. Analyses of children controlled for children's age and sex and all baseline characteristics, with the exception of parental sex; analytic procedures also accounted for multisibling households.

To supplement these regression analyses, which in all likelihood represent an underestimation of the program's effects because of the relatively low take-up rate, treatment-on-treated (TOT) effects were estimated with 2-stage least squares regression or instrumental variable analysis.[15,16] The first model used random assignment status as an instrument (plus baseline covariates) to predict program compliance for the experimental and Section 8 groups (separate models); the subsequent models used the predicted compliance variable for the respective group (plus baseline covariates) to estimate the program's effects on each outcome. These analyses provide a relatively unbiased estimate of the program's effects among those who received treatment.

All statistics were weighted to reduce biases associated with differential ratios of random assignment to the 3 conditions throughout the randomization period. All analyses of parents were estimated with SPSS 8.0 for Windows (SPSS Inc, Chicago, Ill), and all analyses of children were estimated with Stata 6.0 for Windows (Stata Corp, College Station, Tex).

RESULTS

Neighborhood Conditions

Table 2 presents characteristics of the neighborhoods in which families resided at follow-up. According to all neighborhood indicators, experimental families lived in the most advantaged neighborhoods. As measured by the 1990 US Census, experimental families' neighborhoods had significantly higher median incomes and significantly fewer poor residents and rental units than did in-place control families' neighborhoods. Experimental families' neighborhoods did not significantly differ from in-place control families' neighborhoods in terms of the percentage of Blacks, but did differ with respect to the percentage of Latinos and Whites. Experimental parents reported significantly less physical and social disorder and significantly greater satisfaction with their neighborhoods compared with in-place control parents. Interviewers also rated the external environments of experimental families' homes as significantly higher in quality than those of in-place control families' homes.

TABLE 2—Neighborhood Characteristics at Follow-Up by Treatment Group: MTO Demonstration: New York City, 1998–2000

	Experimental (n = 220)	Section 8 (n = 181)	In-Place Control (n = 149)	Difference: Experimental vs Control[a]	Difference: Section 8 vs Control[a]
1990 US Census[b]					
Median family income, $	23 277 (14 684)	17 922 (9283)	14 808 (6531)	+8469†	+3114**
Fraction poor	0.34 (0.20)	0.40 (0.14)	0.45 (0.12)	–0.11†	–0.05**
Fraction rental units	0.82 (0.25)	0.92 (0.15)	0.94 (0.15)	–0.12†	–0.02
Fraction Black	0.45 (0.25)	0.40 (0.24)	0.41 (0.21)	0.04	–0.01
Fraction Latino	0.41 (0.25)	0.48 (0.23)	0.51 (0.20)	+0.10†	–0.03
Fraction White	0.12 (0.21)	0.09 (0.18)	0.06 (0.16)	+0.06**	+0.03
Parental report[c]					
Disorder[d]	2.05 (0.73)	2.17 (0.65)	2.38 (0.56)	–0.33†	–0.21***
Satisfaction[e]	3.07 (1.42)	2.83 (1.33)	2.58 (1.39)	+0.49†	+0.25*
Interviewer observation[b]					
Poor external environment[f]	2.27 (1.40)	2.45 (1.31)	2.72 (1.16)	–0.45***	–0.27

Note. MTO = Moving to Opportunity for Fair Housing Demonstration. Means (SDs) are weighted by date of random assignment because the assignment ratio for the 3 groups changed throughout the randomization period.
[a]Significance levels indicate significant difference compared with in-place controls.
[b]Test statistic computed via analysis of variance, with mean comparisons Bonferroni-adjusted.
[c]Means adjusted for baseline characteristics: parental sex, race/ethnicity, age, education, employment status, marital status, and number of children in household; missing baseline characteristics were imputed to the mean of the nonmissing sample. Test statistics were computed via ordinary least squares regression.
[d]Parents reported "how big a problem" 5 types of events in the neighborhood were, on a 3-point scale from "a big problem" (3) to "not a big problem" (1). For disorder scale, range = 1–3.
[e]For satisfaction, range = 1–5.
[f]Interviewer observed the street block on 4 attributes, and items were recoded dichotomously, with higher scores reflecting lower quality (range 0–4).
*$P < .10$; **$P < .05$; ***$P < .01$; †$P < .001$.

The neighborhoods of Section 8 families also appeared to be superior to the origin neighborhoods of in-place control families, but differences were about half the size of those found for experimental families. Section 8 families lived in neighborhoods with significantly higher incomes and fewer poor residents than did in-place controls, but these families' neighborhoods did not significantly differ in terms of renters or racial/ethnic composition. Section 8 parents also reported significantly less disorder than did in-place control parents. No significant differences between Section 8 and in-place control families were found in neighborhood satisfaction or the quality of the external environment.

Parents' Mental Health

Table 3 displays the groups' total symptom scores; the first column presents predicted means for in-place controls and the following columns presents ITT and TOT effects for the experimental and Section 8 groups, respectively. For the ITT analyses, a significant group difference was found for distress symptoms; experimental parents were less likely than in-place control parents to report distress symptoms. For the TOT analysis, this effect was significant, suggesting that experimental parents who complied with treatment (i.e., moved) were less likely than in-place controls to report distress symptoms. This TOT effect represented an additional 20% reduction in symptoms compared with control parents (e.g., $[0.55 - 0.21 = 0.34]/1.68$). A trend-level ITT effect was found for depressive problems, and the TOT effect was significant.

Children's Mental Health

Table 4 presents group comparisons of subscale scores in the same format used for parents' mental health. All analyses were run for the full sample and separately by children's sex and age.

Full Sample. For the ITT analyses, experimental children were significantly less likely than in-place control children to report anxious/depressive problems, and results were also significant for the TOT analyses. Section 8 children, on the other hand, were only marginally less likely than in-place controls to report dependency and headstrong problems. No significant group differences were found for antisocial problems.

Sex Subgroups. Results varied by the children's sex. Experimental boys were significantly less likely to report anxious/depressive problems than were in-place control boys. For the TOT analyses, this effect was substantially larger than the ITT effect—39% additional reduction in problems—but only marginally significant. Both experimental and Section 8 boys had fewer dependency problems than did in-place control boys, and for boys whose families complied with the program, there was a more than 60% further reduction in these problems compared with in-place controls. For boys, no significant group differences were found for headstrong and antisocial problems, and for girls, no significant group differences were found for any subscale scores.

Age Subgroups. Results also varied by children's age. Among children aged 8 to 13 years, Section 8 children were significantly less likely than in-place controls to have headstrong problems, and the corresponding TOT effect was significant. For anxious/depressive problems, a marginally significant treatment effect was found for experimental children aged 8 to 13 years, and for dependency problems, marginally significant program effects were found for both experimental and Section 8 children aged 8 to 13 years. No significant group differences were seen for antisocial problems or for youths aged 14 to 18 years.

Family Economic Well-Being

No significant program effects were found for employment, welfare receipt, household size, household income, or per-person income for either the ITT or the TOT analyses (Table 3).

DISCUSSION

MTO was the first study to use experimental data to demonstrate links between neigh-

TABLE 3—Summary of Unstandardized Regression Coefficients (Standard Errors) for MTO Program Effects on Parental Mental Health and Family Economic Well-Being at Follow-Up: New York City, 1998–2000

	In-Place Control (n = 149), Predicted Mean	Experimental[a] (n = 220)		Section 8[a] (n = 181)	
		Intent-to-Treat	Treatment-on-Treated	Intent-to-Treat	Treatment-on-Treated
Parental mental health					
Depressive symptoms[b]	2.37	–0.19 (0.11)*	–0.49 (0.25)**	–0.01 (0.11)	0.00 (0.30)
Distress/anxiety symptoms[b]	1.68	–0.21 (0.09)***	–0.55 (0.21)***	–0.12 (0.09)	–0.28 (0.24)
Family economic well-being					
Parent employed	0.47	0.04 (0.24)	0.02 (0.13)	0.30 (0.25)	0.14 (0.14)
Receive welfare	0.70	0.16 (0.24)	0.08 (0.11)	–0.14 (0.25)	–0.07 (0.14)
Household income, $	12 477	287.41 (994.72)	704.19 (2352.44)	146.26 (1035.83)	521.32 (1030.24)
Per person income, $	4 423	573.28 (385.59)	1 347.10 (1013.21)	6.53 (401.53)	147.01 (997.04)

Note. MTO = Moving to Opportunity for Fair Housing Demonstration. Models adjust for parental sex, race/ethnicity, age, education, employment status, marital status, and number of children in household and apply weights by date of random assignment because the assignment ratio for the 3 groups changed throughout the randomization period. Missing baseline characteristics were imputed to the mean of the nonmissing sample.
[a]Significance levels indicate significant difference compared with in-place controls.
[b]Parents reported "how much they were bothered or troubled" during the past month with each symptom, on a 5-point scale from "not at all" (1) to "all of the time" (5); scale scores are averages.
*$P < .10$; **$P < .05$; ***$P < .01$.

borhood residence and mental health by providing families the opportunity to move (via randomization) from public housing in high-poverty neighborhoods into private housing in less poor neighborhoods. The experimental design addressed the fundamental problem of selection bias in neighborhood research. Neighborhood effects on mental health were found for parents and children. Because children reported on their own mental health, no confounding of reporters was present.

The most significant benefits of the MTO program were noneconomic. Experimental parents who moved to low-poverty neighborhoods displayed superior mental health, as evidenced by their reporting fewer distress and depressive symptoms than in-place control parents who remained in high-poverty neighborhoods. Experimental parents showed moderate relative improvements in mental health ranging from 8% to 33% for ITT and TOT effects, respectively.

The mental health impacts of the MTO program were larger for children than for parents. Program effects were most pronounced for boys and for children aged 8 to 13 years. Among boys, moving to private housing in low-poverty neighborhoods resulted in a 25% reduction in depressive/anxiety and dependency problems, on average, relative to in-place controls, and effects increased threefold for boys whose families complied with the program by using vouchers to move to advantaged neighborhoods.

Similar results for dependency problems were found for Section 8 boys who moved out of public housing but remained in relatively poor neighborhoods. In addition, Section 8 children aged 8 to 13 years displayed fewer headstrong problems compared with in-place control peers.

The general lack of findings for girls may owe to girls' differential exposure to neighborhood contexts. Parents and school officials may provide boys greater access to neighborhood influences, whereas girls' exposure may be more restricted.[17,18] The absence of findings for youths aged 14 to 18 years may result from their ability to travel back to their old high-poverty neighborhoods or from disruption of peer networks, which are salient during adolescence. In fact, research on residential mobility indicates that instability created by moving and subsequent school changes (independent of accompanying economic changes) may have negative health effects, likely owing to disturbance of social networks.[19–22] Finally, younger children may benefit more from their parents' superior mental health than older children, given the prominence of the family context for this age group.[23]

Although our measures did not permit examination of clinical disorders, the program's impact on mental health, particularly the large effects for children, may have clinical as well as public health benefits. For instance, the favorable results reported correspond with other MTO site evaluations, particularly reductions in male youths' arrests for violent crime and improvements in children's health for incidents necessitating medical intervention.[24,25] In addition, results partially concur with findings from recent welfare-to-work studies suggesting that both parents and their children are affected by antipoverty programs.[27] Although several studies report modest beneficial effects of antipoverty programs on parents' mental health, effects for their children are mixed, with possibly more pronounced effects for children and potentially adverse effects for adolescents' well-being. No such negative effects were found in the MTO program.

The absence of program effects on family economic well-being—parental employment, welfare receipt, and income—may owe to several factors. First, the MTO program coincided with historic changes in welfare legislation, which promoted entrance into the workforce and made cash assistance contingent on employment as well as time-limited. Second, the program was initiated during a

TABLE 4—Summary of Unstandardized Regression Coefficients (Standard Errors) for MTO Program Effects on Children's Mental Health at Follow-Up: New York City, 1998–2000

	In-Place Control (n = 146), Predicted Mean	Experimental[a] (n = 195)		Section 8[a] (n = 171)	
		Intent-to-Treat	Treatment-on-Treated	Intent-to-Treat	Treatment-on-Treated
Anxious/depressed (total)[b]	2.02	−0.32 (0.16)**	−0.85 (0.41)**	−0.16 (0.17)	−0.45 (0.48)
Boys	2.02	−0.42 (0.21)**	−1.20 (0.65)*	−0.33 (0.24)	−1.12 (0.73)
Girls	2.02	−0.23 (0.23)	−0.64 (0.56)	−0.03 (0.24)	−0.09 (0.65)
Aged 8–13 y	2.15	−0.39 (0.21)*	−0.90 (0.49)*	−0.26 (0.23)	−0.74 (0.62)
Aged 14–18 y	1.80	−0.20 (0.22)	−0.67 (0.68)	0.01 (0.23)	−0.04 (0.71)
Dependent (total)[b]	1.58	−0.16 (0.14)	−0.47 (0.35)	−0.28 (0.15)*	−0.73 (0.43)*
Boys	1.75	−0.53 (0.20)***	−1.61 (0.66)***	−0.64 (0.21)†	−1.74 (0.69)***
Girls	1.42	0.17 (0.19)	0.35 (0.49)	0.04 (0.20)	0.19 (0.54)
Aged 8–13 y	1.80	−0.29 (0.18)*	−0.77 (0.41)*	−0.33 (0.20)*	−0.83 (0.53)*
Aged 14–18 y	1.21	0.07 (0.21)	0.22 (0.63)	−0.18 (0.21)	−0.56 (0.68)
Headstrong (total)[b]	2.64	−0.08 (0.18)	−0.25 (0.46)	−0.32 (0.19)*	−0.94 (0.54)*
Boys	2.58	−0.02 (0.27)	0.04 (0.78)	−0.43 (0.27)	−1.40 (0.84)*
Girls	2.69	−0.11 (0.26)	−0.41 (0.64)	−0.24 (0.26)	−0.63 (0.72)
Aged 8–13 y	2.58	−0.04 (0.23)	−0.13 (0.52)	−0.55 (0.20)**	−1.32 (0.65)**
Aged 14–18 y	2.73	−0.10 (0.29)	−0.25 (0.88)	−0.06 (0.30)	−0.27 (0.94)
Antisocial (total)[b]	1.69	0.29 (0.20)	0.78 (0.53)	0.01 (0.20)	0.02 (0.56)
Boys	1.79	0.34 (0.29)	1.08 (0.84)	0.34 (0.31)	0.88 (0.92)
Girls	1.61	0.27 (0.28)	0.80 (0.72)	−0.31 (0.28)	−0.87 (0.76)
Aged 8–13 y	1.60	0.19 (0.25)	0.45 (0.61)	−0.05 (0.25)	−0.16 (0.66)
Aged 14–18 y	1.85	0.46 (0.33)	1.53 (1.04)	0.07 (0.35)	0.21 (1.07)

Note. MTO = Moving to Opportunity for Fair Housing Demonstration. Models adjust for children's age and sex (full sample only) and baseline parental characteristics (race/ethnicity, age, education, employment status, marital status, and number of children in the household) and apply weights by date of random assignment (because the assignment ratio for the 3 groups changed throughout the randomization period). Missing baseline characteristics were imputed to the mean of the nonmissing sample. Standard errors adjust for multisibling households.
[a]Significance levels indicate significant difference compared with in-place controls.
[b]Children reported "how true of them" behaviors were during the past 6 months, on a 3-point scale, and the scale was recoded to reflect "not true" (0) or "sometimes/often true" (1); scale scores are sums.
*P < .10; **P < .05; ***P < .01; †P < .001.

period of general economic growth, which improved the labor market prospects for most sectors of the population.[27] Third, low- to medium-skill jobs were not necessarily more plentiful in New York suburbs compared with cities such as Atlanta and Boston.[28,29] Fourth, transportation issues, such as inadequate public transportation and lack of access to cars, may have impeded entrance into the workforce for suburban movers. Finally, moving may have disrupted existing job networks.

Because this study used an experimental design, we cannot disentangle the processes that might underlie the effects of the program; however, a range of neighborhood and family economic conditions was examined. At baseline, the prevalence of neighborhood crime and violence in families' lives was clear from the fact that escaping drugs and gangs was their primary reason for volunteering for the program. By and large, mover families, particularly experimental families, acquired considerably improved neighborhood conditions, which included higher median incomes and less reported disorder relative to the baseline neighborhoods of in-place control families. In addition to improved neighborhoods, another possible explanation for the program's effects is enhanced family economic well-being[30,31]; however, as noted, no significant group differences were found. Finally, an alternative hypothesis is that more advantaged neighborhoods provide better health and social resources—such as quality health services, schools, and housing, as well as youth programs, parks, and sport facilities—than poor neighborhoods.

A major limitation of this study is that only approximately 70% of New York MTO families were seen at follow-up. However, the present sample does not significantly differ from nonparticipants in baseline characteristics. In addition, the MTO program is based on voluntary participation, which suggests that beneficial effects of the program may be due, at least in part, to unmeasured family characteristics that led to self-selection into MTO. Nonetheless, more advantaged and motivated families did not appear to volunteer for MTO, as indicated by the fact that participating MTO families were more socioeconomically disadvantaged than families that declined participation.[9] Finally, the absence of repeated measures on outcomes, as a result of restricted baseline measures, did not allow examination of within-group change by means of before-and-after comparisons; it is unclear whether the program's effects are over- or underestimated by failure to consider within-group differences.

One policy implication of this study is that neighborhood residence is a possible source of socioeconomic differentials in health. Neighborhood disorder and associated conditions in high-poverty communities also may contribute to high rates of emotional distress.[32,33] Our findings suggest that moving out of public housing in high-poverty neighborhoods had positive effects on mental health, although the effects varied for parents and their children, depending on the nature of the relocation. High-density public housing located in distressed communities is being dismantled in several large cities. Our study suggests potential mental health benefits from this policy, especially for families that relocate to low-poverty neighborhoods. Public health efforts to monitor the mental health of families in high-poverty neighborhoods are merited, as are policies to increase the mobility options of low-income families. ■

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Contributors

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References

1. Massey DS, Denton NA. *American Apartheid: Segregation and the Making of the Underclass.* Cambridge, Mass: Harvard University Press; 1993.

2. Wilson WJ. *The Truly Disadvantaged: The Innercity, the Underclass, and Public Policy.* Chicago, Ill: University of Chicago Press; 1987.

3. Leventhal T, Brooks-Gunn J. The neighborhoods they live in: effects of neighborhood residence upon child and adolescent outcomes. *Psychol Bull.* 2000; 126:309–337.

4. Mayer SE, Jencks C. Growing up in poor neighborhoods: how much does it matter? *Science.* 1989; 243:1441–1445.

5. Tienda M. Poor people and poor places: deciphering neighborhood effects on poverty outcomes. In: Huber J, ed. *Macro-Micro Linkages in Sociology.* Newbury Park, Calif: Sage Publications; 1991:244–262.

6. Rubinowitz LS, Rosenbaum JE. *Crossing the Class and Color Lines: From Public Housing to White Suburbia.* Chicago, Ill: University of Chicago Press; 2000.

7. Rosenbaum JE, Popkin SJ. Employment and earnings of low-income blacks who move to middle-class suburbs. In: Jencks C, Peterson P, eds. *The Urban Underclass.* Washington, DC: Brookings Institution; 1991: 342–356.

8. Feins JD, Holin MJ, Phipps A. *Moving to Opportunity for Fair Housing Program Operations Manual.* Cambridge, Mass: Abt Associates; 1996.

9. Goering J, Kraft J, Feins D, McInnis D, Holin MJ, Elhassan H. *Moving to Opportunity for Fair Housing Demonstration Program: Current Status and Initial Findings.* Washington, DC: US Dept of Housing and Urban Development; 1999.

10. Goering J, ed. *Choosing a Better Life? Evaluating the Moving to Opportunity Social Experiment.* Washington, DC: Urban Institute Press. In press.

11. Kandel DB, Davies M. Depressive Mood Inventory. Epidemiology of depressive mood in adolescents: an empirical study. *Arch Gen Psychiatry.* 1982;39: 1205–1212.

12. Rickels K, Garcia CR, Lipman RS, Derogatis LR, Fisher EL. Hopkins Symptom Checklist: assessing emotional distress in obstetric-gynecologic practice. *Prim Care.* 1976;3:751–764.

13. Peterson JL, Zill N. Marital disruption, parent-child relationships, and behavior problems in children. *J Marriage Fam.* 1986;48:295–307.

14. Zill N. *Behavior Problem Scales Developed From the 1981 Child Health Supplement to the National Health Interview Survey.* Washington, DC: Child Trends; 1985.

15. Bloom HS. Accounting for no-shows in experimental evaluation designs. *Eval Rev.* 1984;8:225–246.

16. Angrist JD, Imbens GW, Rubin DB. Identification of causal effects using instrumental variables. *J Am Stat Assoc.* 1996;91:444–455.

17. Ensminger ME, Lamkin RP, Jacobson N. School leaving: a longitudinal perspective including neighborhood effects. *Child Dev.* 1996;67:2400–2416.

18. Entwisle DR, Alexander KL, Olson LS. The gender gap in math: its possible origins in neighborhood effects. *Am Sociol Rev.* 1994;59:822–838.

19. Astone NM, McLanahan SS. Family structure, residential mobility, and school drop out: a research note. *Demography.* 1994;31:575–584.

20. Duncan GJ, Yeung WJ, Brooks-Gunn J, Smith JR. How much does childhood poverty affect the life chances of children? *Am Sociol Rev.* 1998;63: 406–423.

21. Haveman R, Wolfe B, Spaulding J. Child events and circumstances influencing high school completion. *Demography.* 1991;28:133–158.

22. Rutter M. Stress, coping, and development: some issues and some questions. *J Child Psychol Psychiatry.* 1981;22:232–356.

23. McLoyd VC. The impact of economic hardship on black families and children: psychological distress, parenting, and socioemotional development. *Child Dev.* 1990;61:311–346.

24. Katz LF, Kling JR, Liebman JB. Moving to Opportunity in Boston: early results of a randomized mobility experiment. *Q J Economics.* 2001;116:607–654.

25. Ludwig J, Duncan GJ, Hirschfield P. Urban poverty and juvenile crime: evidence from a randomized housing-mobility experiment. *Q J Economics.* 2001;116: 655–679.

26. Morris PA, Huston AC, Duncan GJ, Crosby DA, Bos JM. *How Welfare and Work Policies Affect Children: A Synthesis of Research.* New York: The Next Generation, Manpower Demonstration Research Corporation; 2001.

27. Cherry R, Williams MRE. *Prosperity for All? The Economic Boom and African Americans.* New York: Russell Sage; 2000.

28. Bluestone B, Stevenson MH. *The Boston Renaissance: Race, Space, and Economic Change in an American Metropolis.* New York: Russell Sage; 2000.

29. Sjoquist DL, ed. *The Atlanta Paradox.* New York: Russell Sage; 2000.

30. Adler NE, Boyce WT, Chesney MA, Folkman S, Syme SL. Socioeconomic inequalities in health: no easy solution. *JAMA.* 1993;269:3140–3145.

31. Adler NE, Boyce WT, Chesney MA, et al. Socioeconomic status and health: the challenge of the gradient. *Am Psychol.* 1994;49:15–24.

32. McEwen BS. Protective and damaging effects of stress mediators. *N Engl J Med.* 1998;338:171–179.

33. McEwen BS, Seeman T. Protective and damaging effects of mediators of stress. Elaborating and testing the concepts of allostasis and allostatic load. *Ann N Y Acad Sci.* 1999;896:30–47.

Relative Influences of Individual, Social Environmental, and Physical Environmental Correlates of Walking

Billie Giles-Corti, PhD, and Robert J. Donovan, PhD

Objectives. This study sought to examine individual, social environmental, and physical environmental correlates of walking.

Methods. A cross-sectional survey was conducted among healthy workers and homemakers residing in metropolitan Perth, Western Australia.

Results. Most respondents walked for transport or recreation, but only 17.2% did a sufficient amount of walking to accrue health benefits. After adjustment, the relative influences of individual, social environmental, and physical environmental factors were found to be almost equally important.

Conclusions. Although walking is popular, few people do enough walking to benefit their health. Those who walk as well as engage in other physical activities appear more likely to achieve recommended levels of activity. Promoting walking may require a comprehensive strategy. (*Am J Public Health.* 2003;93:1583–1589)

Walking was placed firmly on the public health agenda in 1996 after publication of the US surgeon general's report on physical activity.[1,2] After reviewing decades of epidemiological evidence, the surgeon general concluded that physical inactivity was as important a disease risk factor as smoking and unhealthy diets. Moreover, evidence showed that individuals could derive health benefits by engaging in as little as 30 minutes of moderate exercise each day, including brisk walking.

Studies consistently show that walking is a popular activity among both men and women, but particularly among women and individuals older than 50 years.[3,4] However, fewer published studies have examined the factors that influence walking than have assessed factors associated with engaging in vigorous exercise.

Recently, there has been considerable interest in the environmental influences of physical activity.[5–7] In the present study, we examined the relative influences of individual, social environmental, and objectively measured physical environmental factors on a single form of physical activity: walking (see Giles-Corti and Donovan[8] for details regarding the social–ecological model adopted).

METHODS

Full details of the study methods can be found elsewhere.[8] Briefly, the study, conducted between August 1995 and March 1996, involved healthy homemakers and workers aged 18 to 59 years who resided in a 408-km^2 area of metropolitan Perth, Western Australia. Perth has a population of about 1.2 million, and its residents enjoy a relatively high standard of living in comparison with residents of other Australian cities.

As a means of controlling for potentially confounding variables, individuals with reasons not to engage in recreational physical activity (e.g., owing to illness or being physically active at work) were excluded. One eligible respondent was randomly selected from each household surveyed (the person whose birthday fell closest to the day of the interview). After 3 callbacks, a household response rate of 52.9% was achieved.

The Australian Bureau of Statistics drew a probability cluster sample from the study population. The final sample included 1803 respondents from 277 districts (939 from the 80th percentile and above in terms of socioeconomic advantage and 874 from the 20th percentile or below).[9] Two qualitative studies that assisted in the development of a social ecological model of physical activity preceded the main study.[10,11]

Variables

Full details regarding the variables used are available elsewhere.[8] Table 1 lists the subset of individual, social environmental, and physical environmental variables used in this study to examine factors associated with walking.

Physical environmental variables were measured objectively. Interviewers assessed the street on which the interview household was located to determine access to footpaths, shops, trees, and minor roads. A spatial access model[12] was used in measuring access to public open spaces, rivers, and beaches. This model assessed spatial distributions of facilities adjusted for the *distance of decay* factor, a measure of people's desire and ability to overcome distance or travel time to access facilities.[12] While use of a facility is inversely related to one's distance from the facility, the extent of the distance of decay factor depends on the attractiveness of the destination (i.e., its attributes), its location, and the user's access to transportation.[12]

The accessibility model that examined use of the rivers, beaches, and golf courses has been described elsewhere.[8] The model that assessed access to public open spaces adjusted for attractiveness, size, and distance via the following equation:

$$1)\qquad A_i = \sum_j m_j^{\alpha} s_j^{\lambda} / d_{ij}^{\beta},$$

where A_i is the access index at origin i; m_j is the attractiveness of destination j; s_j is the size of destination j; d_{ij} is the distance between origin i and destination j; α is an estimated destination-specific attractiveness-decay parameter between i and j; λ is an estimated destination-specific size-decay parameter between i and j; and β is an estimated destination-specific distance-decay parameter between i and j.

Attractiveness scores were based on weighted average scores indicating the presence or absence of certain attributes in the study area's 516 public open spaces more than 2 acres in size.[17] Modified weights were derived from a survey of urban planners in each of the local councils represented in the study area, who were asked to allocate 100

TABLE 1—Independent Variables Used in the Model

	Mode of Measurement	Scale
Individual cognitive variables		
Attitude toward process of trying to exercise[13]	How "unpleasant/pleasant," "difficult/easy," or "bad/good" the process of trying to do a regular exercise routine[a] would be "regardless of whether you succeed or fail"[b]	7 point: –3 to 3
Frequency of past attempts[13]	During the past 3 months, how many times, if any, did you try to do a regular physical activity routine?[a]	5 point: 1 = never, 5 = weekly
Perceived behavioral control[14]	Assuming that you tried to do a regular exercise routine[a] over the next 2 weeks, how likely or unlikely is it that you would actually stick to your routine?	7 point: 1 = very unlikely, 7 = very likely
Behavioral skills used in the past month[15]	How frequently in the last month did you: set a goal for how much physical activity you would like to do; plan particular days on which you would do physical activity; and arrange to meet someone to do physical activity with?[a]	5 point: 1 = never, 5 = weekly
Intention to try in the next 2 weeks[14]	Before this interview, how likely or unlikely is it that in the next 2 weeks you would try to do a regular exercise routine?[a]	7 point: 1 = very unlikely, 7 = very likely
Social environmental variables		
Dog ownership	Do you have a dog in this household?	1 = yes, 0 = no
Club membership	Are you a member of a sport, exercise, or outdoor recreational group or club?	1 = yes, 0 = no
Frequency of participation in physical activity by 5 significant others[16]	How often over the last month did the following people[c] do physical activity, including walking?	5 point: 1 = never, 5 = more than once a week[d,e]
Frequency of a significant other doing physical activity with respondent[16]	Over the past 3 months, which of these people,[c] if any, did a physical activity with you, including walking?	4 point: 0 = never, 4 = weekly[d,f]
Physical environmental variables		
Functional environment	Interviewer noted whether a sidewalk (on both sides or one side of street) or shop was visible on the street	4 categories: no sidewalk or shop; no sidewalk but shop; sidewalk but no shop; both sidewalk and shop
Appeal of environment	Interviewer noted the type of street (cul de sac, minor local road, major local road, highway or major thoroughfare) and whether the street was tree lined; had good (more than one tree to a block), medium (one tree per block), poor (less than one tree per block), or mixed tree coverage; or had no trees	4 categories: major traffic and no trees; major traffic and some trees; minor traffic and no trees; minor traffic and some trees
Overall spatial access to attractive public open space, river, beach, golf courses[g]	Total spatial access to each of these facilities measured on a continuous scale and recoded into 4 categories	4 categories: 1 = bottom quartile of access, 4 = top quartile of access

[a]Respondents were given a choice of preferred exercise, either three 20-minute sessions of vigorous exercise each week or 30 minutes to 1 hour of light to moderate exercise each day.
[b]Recoded as the mean of the sum of these 3 items.
[c]Spouse or partner, close family members, people at work, close friends and people in neighborhood (based on items developed by Sallis and colleagues[32]).
[d]After an initial examination of the results, these variables were recoded to 1 (more than once a week) and 0 (all other responses). A single item, "number of significant others who did physical activity," was developed.
[e]More than once per week in the past month.
[f]Weekly with the respondent in the past 3 months.
[g]For full details of how the spatial access variables were developed, see Giles-Corti and Donovan.[8]

points to 10 attributes that might contribute to open spaces being used for physical activity.[17] In the current study, which focused on adults, only 9 attributes were included in the overall score (presence of children's play equipment was excluded, and the weights of the remaining attributes were reallocated to sum to 100).

The overall weighted score was based on the presence or absence of (1) shady trees on paths (canopies of many trees touch [weighted value of 14.3], canopies of some trees touch [11.4], canopies do not touch but trees close together [8.6], canopies of trees do not touch and trees are spread apart [5.7], tree coverage sparse [2.86], no trees along paths [0]), (2) irrigated lawns (15.3), (3) walking paths (13.9), (4) sports facilities (13.9), (5) near beach or river (13.1), (6) water-associated features (e.g., lake pond) (8.3), (7) quiet surrounding roads (i.e., a cul-de-sac or minor roads only [8.0]), (8) artifical lighting (6.8), and (9) bird life (3.8). The attractiveness score for each public open space was estimated via the following equation:

$$\text{2)} \qquad \text{Att} = \sum_j A_j \times w_j,$$

where Att is the attractiveness score, A is a binary indicator (0 or 1) of the presence of the

jth attribute and w_j is the weight for the jth attribute.

Destination-specific decay parameters were estimated for attractiveness, size, and distance (see Giles-Corti and Donovan[8] for details of the method used). Briefly, these estimations involved the use of a linear regression model in which the log values for attractiveness, size, and distance were separately regressed on the log value for percentage of opportunities available to access the facilities used.

The exponential coefficients from the linear regressions used as the decay parameters in subsequent modeling were 1.91 for distance, 0.52 for attractiveness, and 0.85 for size. An exponential coefficient of less than 1 indicates that (all else being equal) as the attractiveness and size of a public open space double, use increases by less than one half. A decay of distance parameter of more than 1 indicates that when distance doubles, facility use reduces by more than one half. The sizes of these coefficients indicate that use of public open space is sensitive to distance and that the size of the space is more likely than its other attributes to attract users. However, the attractiveness, distance, and size model was retained because the attractiveness of existing parks, unlike their size, can be modified.

The physical activity items were based on a modified version of items previously used in Australian studies.[18] Separate measurements were made of respondents' frequency and total duration of walking for transport and walking for recreation in the previous 2 weeks. The dependent variable was "walking at recommended levels" (1=yes, 0=no), defined as 12 or more sessions of walking in the previous 2 weeks totaling 360 minutes or more.

Statistical Analysis

The present analysis was based on 1773 respondents who reported in-scope physical activity data (i.e., 30 participants were excluded because they appeared to overreport their activity levels). We undertook the analysis using SPSS.[19] After creating scales for the individual cognitive variables comprising multiple items, we assessed internal consistency. Results of these assessments showed that consistency values ranged from 0.71 to 0.86, indicating satisfactory internal consistency.

We tested the social ecological model using unconditional logistic regression analyses. Variables for inclusion in the final model were assessed in terms of whether they were statistically ($P<.05$), empirically (point estimates at least 20% greater or lower than the reference category), or theoretically important (regardless of the empirical results). However, in the interest of parsimony, we assessed theoretical importance by examining the width of the confidence intervals before making a final decision to include a variable in the final model. This approach allowed a new ecological model to be developed that combined individual, social environmental, and physical environmental variables. The independent variables included in the final model were adjusted for age, gender, number of children younger than 18 years living at home, household income, and education.

To examine the relative influence of individual, social environmental, and physical environmental determinants, we summarized 3 "classes" of determinants (i.e., individual, social environmental, and physical environmental; referred to as "determinant scores") and the demographic factors into multivariate summary scores.[20] Our development of multivariate summary scores was based on a method outlined by Miettinen.[20] He proposed using a single multivariate summary score made up of potential confounding variables that, when grouped into categories, could be used for cross-classification purposes. This scoring technique was developed to overcome inefficiency in analyses that require control of a large number of covariates. In this study, the individual, social environmental, and physical environmental determinant scores were grouped into tertiles representing low, medium, and high "risk," and demographic scores were grouped into deciles.

RESULTS

Types and Levels of Activity

Our results confirmed that walking is a popular form of physical activity: in the 2 weeks preceding the survey, 72.1% of respondents had walked for transport, and 68.5% had walked for recreation. However, only 17.2% did a sufficient amount of walking to be classified as walking at recommended levels (6 sessions totaling 180 minutes or more per week).

To estimate the overall level of physical activity in the study population, we asked respondents whether they participated in a number of types of physical activity: light to moderate activities (e.g., gardening, heavy household chores), vigorous activities (e.g., jogging, aerobics, or vigorous swimming), and walking (either for transport or for recreation). Table 2 shows that the majority (66.5%) of respondents reported engaging in a combination of physical activities. Only 7.4% of respondents reported exclusively walking for transport, and 13.1% reported exclusively walking for recreation. Of those who engaged in a combination of activities, 78.2% achieved recommended levels of physical activity, as compared with 13.6% of those who walked for transport only and 31.7% of those who walked for recreation only.

TABLE 2—Types of Activity Undertaken During Past 2 Weeks, by Physical Activity Level: Perth, Australia, 1995–1996

	Physical Activity Level			
Type(s) of Physical Activity Undertaken	No.	Insufficient, %	Sufficient, %[a]	As % of Total Sample
None	77	100.0	0.0	4.3
Recreational walking only	233	68.2	31.7	13.1
Walking for transport only	132	86.4	13.6	7.4
Vigorous activity only	82	29.3	70.3	4.6
Light to moderate activity only	70	70.0	30.0	3.9
Combination	1179	21.9	78.2	66.5

[a]Defined as the equivalent of 30 minutes of moderate activity on most days of the week.[1,2]

TABLE 3–Associations Between Walking at Recommended Levels and Individual, Social Environmental, and Physical Environmental Determinants: Logistic Regression Odds Ratios

Determinant	Final Model Odds Ratio (n = 1688)[a]	95% Confidence Interval	*P*
Attitude toward process			
Negative/neutral[b]	1.00		
Positive	1.23	0.79, 1.91	.361
Very positive	1.45	0.89, 2.35	.133
Frequency of attempts in past 3 months			
Never[b]	1.00		
1–2 times	1.16	0.58, 2.29	.680
Once a month	1.19	0.50, 2.82	.700
2–3 times a month	0.57	0.28, 1.19	.136
Weekly	1.43	0.92, 2.22	.118
Perceived behavioral control			
Low/uncertain[b]	1.00		
High	1.48	1.00, 2.19	.050
Frequency of behavioral skill use used in past month			
Never[b]	1.00		
Once	0.80	0.52, 1.24	.302
2–3 times	0.61	0.39, 0.97	.036
Weekly	0.68	0.42, 1.10	.110
More than once a week	0.53	0.30, 0.93	.026
Intention to be physically active in next 2 weeks			
Low[b]	1.00		
Medium	1.15	0.70, 1.76	.645
High	1.83	1.14, 2.94	.013
Sport, recreation, or outdoor club membership			
No[b]	1.00		
Yes	0.54	0.39, 0.75	.000
Dog ownership			
No[b]	1.00		
Yes	1.58	1.19, 2.09	.002
No. of significant others known to exercise weekly in past month			
0[b]	1.00		
1	1.15	0.76, 1.73	.511
2	1.24	0.80, 1.92	.342
3	1.07	0.66, 1.73	.779
4 or more	1.32	0.77, 2.25	.310
No. of significant others who exercised with respondent weekly over past 3 months			
0[b]	1.00		
1	1.81	1.30, 2.52	.000
2	2.05	1.36, 3.09	.001
3	1.48	0.75, 2.93	.256
4 or more	3.42	1.14, 10.2	.028
Functional environment			
No sidewalk, no shop[b]	1.00		
No sidewalk, shop	1.34	0.22-8.19	0.753
Sidewalk, no shop	1.23	0.88-1.72	0.223
Sidewalk, shop	1.45	0.82-2.58	0.202

Continued

Factors Associated With Recommended Levels of Walking

After adjustment, walking at recommended levels appeared to be associated with 12 of the 16 independent variables examined (access to a beach, a river, and a golf course were dropped from the final model), although chance could not be ruled out as an explanation for many of these findings (Table 3). With respect to individual variables, the odds of achieving recommended levels of walking were 48% higher among respondents with a high level of perceived behavioral control than among those with a low level of perceived behavioral control (self-control).[14] Also, odds were nearly twice as high for individuals who were highly intent on being physically active in the next 2 weeks as for those not as intent on being active.

Although results were not statistically significant, there was empirical evidence that odds of achieving recommended levels of walking were 45% higher among individuals with a very positive attitude toward the process of being physically active (odds ratio [OR]=1.45, 95% confidence interval [CI]=0.89, 2.35) than among those with a negative or neutral attitude. Also, odds also were 43% higher among those who had attempted to be active weekly during the past 3 months (OR=1.43, 95% CI=0.92, 2.22) than among those who had not made such an attempt.

In terms of the social environment, the odds of achieving recommended levels of walking increased with the number of significant others who had exercised weekly with the respondent during the previous 3 months (test for trend, $P<.001$). Those who exercised with one or more significant others were more likely to walk at the recommended level. Those who had 4 or more exercise partners were 3.42 times more likely to do so. In addition, the odds of walking at recommended levels were 58% higher among those who owned dogs than among those who did not. Knowing significant others who exercised appeared less influential than having others with whom to exercise.

The physical environment also appeared to influence walking at recommended levels. Relative to respondents in the bottom quartile of access to public open space, the odds of

TABLE 3–*Continued*

Appeal of environment			
Major traffic, no trees[b]	1.00		
Major traffic, some trees	1.41	0.89-2.24	0.137
Minor traffic, no trees	1.90	0.98-3.70	0.061
Minor traffic, some trees	1.62	0.98-2.67	0.060
Access to attractive public open space			
Bottom quartile of access[b]	1.00		
3rd quartile	0.76	0.51-1.14	0.185
2nd quartile	1.25	0.85-1.85	0.259
Top quartile	1.47	1.00-2.15	0.048

[a]Adjusted for age, gender, number of children younger than 18 years living at home, household income, and education.
[b]Reference category.

walking at recommended levels were 47% higher among those in the top quartile. In comparison with those who had major traffic and no trees on their street, the odds of achieving recommended levels of walking were nearly 50% higher among those who lived on a street with one or both of these features (combined OR=1.49; 95% CI=0.96, 2.33); however, chance could not be ruled out as an explanation for this result. Similarly, in comparison with those who had no sidewalk and no shop on their street, those who had access to either or both of these attributes were about 25% more likely to achieve recommended levels of walking (combined OR=1.25, CI=0.90, 1.74).

Finally, some of the factors examined were negatively associated with walking. For example, members of sporting, recreational, or outdoor clubs were only half as likely as nonmembers to achieve recommended levels of walking. Also, odds of achieving recommended levels were approximately one third lower among respondents who had used behavioral skills (e.g., setting a goal in regard to amount of physical activity, planning particular days on which to engage in an activity) during the past month, regardless of how frequently, than among those who had not used such skills; however, this result was not statistically significant.

Relative Effects of Factors Influencing Walking

As mentioned, summary scores were developed for the individual, social environmental, and physical environmental determinants examined here (Table 4). The results suggest that the relative influences of these 3 variables were similar. There was no evidence of multiplicative interactions. Relative to respondents in the lowest determinant score categories, the odds of achieving recommended levels of walking were 3.10 times higher among those in the high individual determinant score category, 2.79 times higher among those in the high social environmental determinant score category, and 2.13 times higher among those in the high physical environmental determinant score category.

DISCUSSION

Our results suggest that while walking is popular, few people do a sufficient amount of walking to gain health benefits. In short, more people need to do more walking, and more often, to achieve public health objectives. In addition, very few people who walked for transport only, or who walked for recreation only, achieved recommended levels of physical activity. Our findings indicated that undertaking a combination of physical activities is more likely to result in achieving recommended levels of physical activity.

There appears to be merit in promoting brisk walking—particularly walking for transport—as an activity in its own right as well as an activity to be undertaken in combination with other pursuits. This strategy has the potential to increase physical activity levels in the community as well as prevent the dramatic decreases in activity found when adults stop participating in team sports or other vigorous pursuits; thus, it can help in preventing active people from becoming inactive.[21] Increasing walking for transport also has the potential to reduce automobile dependency and thus meet broader community objectives for a healthier, greener, and safer environment.[22]

TABLE 4—Associations Between Walking at Recommended Levels and Individual, Social Environmental, and Physical Environmental Determinant Summary Scores: Logistic Regression Odds Ratios (n = 1688)

	Odds Ratio: Model With All variables	95% Confidence Interval	*P*
Individual determinant score			
Low[a]	1.00		
Medium	1.65	1.16, 2.35	.006
High	3.10	2.20, 4.37	.000
Social environmental determinant score			
Low[a]	1.00		
Medium	1.50	1.05, 2.14	.027
High	2.79	2.00, 3.90	.000
Physical environmental determinant score			
Low[a]	1.00		
Medium	1.36	0.97, 1.90	.073
High	2.13	1.54, 2.94	.000

Note. Model adjustments were made for demographic determinant scores. No interactions were eligible for inclusion in the model.
[a]Reference category.

Consistent with a social ecological view of health behavior,[5,23,24] the present results suggest that a comprehensive strategy is required to increase community levels of walking. Such a strategy would need to create a supportive social and cultural environment and provide an infrastructure that actively encourages walking and the use of public transport. Our results also suggest that strategies are required to increase and maintain levels of confidence that walking can be incorporated into one's daily activities.[25] In addition, positive attitudes toward the process of being physically active need to be reinforced.

The finding that a positive social environment is likely to influence individual behavior is not new.[25] Encouraging people to walk with others, or even with their dog, is associated with achieving recommended levels of walking. It has been shown that dog owners have fewer cardiovascular risk factors and engage in more recreational exercise than others.[26] Moreover, a large proportion of the population owns dogs (in Australia, for example, nearly 4 million people and 2.6 million households report owning a dog[27]). However, the vast majority of dog owners do not engage in a sufficient amount of walking to be classified as walking at recommended levels[28] and a specific strategy for encouraging more dog owners to walk with their dogs is required.[28]

Aspects of the physical environment also appear to be important. Our results showed that walking at recommended levels was associated with having good access to attractive open spaces in the area of the study. The situation may be different in other countries where fear of crime may prevent the public from using local parks.[28] There was also weak evidence that those who achieved recommended levels of walking were more likely to live on a street that was aesthetically pleasing, with minor traffic, trees, sidewalks, or a local shop. Studies of individuals' perceptions of their local environment show correlations between these perceptions and physical activity levels.[29–31] Thus, there is a need for further studies involving better objective measurements of such variables.[32,33]

There is a growing awareness that neighborhood design can influence local walking practices.[5,22,28,34] Beatley has argued that "sustainable living," including walking, cycling, and using public transport, is difficult in the low-density, automobile-dependent neighborhoods characteristic of the United States[17] and Australia. However, even in densely populated cities, such as those in the United Kingdom and parts of Europe, automobile dependency is increasing at the expense of nonmotorized forms of transport such as walking, cycling, and public transportation.[28,34] If this trend is to be reversed, comprehensive interagency strategies are required to address individual, social environmental, and physical environmental factors.

Encouraging more walking for transport is a means of incorporating physical activity into people's daily routine. A good start would be to encourage people to engage in highly achievable activities such as using stairs instead of elevators, parking further away from their destinations, and exiting public transport one stop before their destination. However, from a broader public health perspective, attempts to encourage active commuting generally will produce other benefits.[28,34] For example, passenger vehicles contribute considerably to greenhouse emissions,[35] and a large proportion of motor vehicle trips in the United States and Australia involve distances of 3 km or less.[35,36]

Several limitations of this study must be considered. As detailed fully elsewhere,[8] Perth is a relatively homogeneous city with above average standards of living relative to other Australian capital cities. As a result of financial and practical constraints, our study was restricted to a 408 km^2 area of Perth, and the sample included only healthy workers and homemakers aged 18 to 59 years as a control for potentially confounding variables. Trained interviewers made objective assessments of access to footpaths, shops, traffic, and an aesthetically pleasing environment, but these environmental assessments were restricted to the street on which the respondent lived. To address this weakness, our group is undertaking a more comprehensive study of the extent to which neighborhoods are conducive to walking and cycling.[32,33]

In addition, an alternative measure of access to public open space may have been more appropriate than the spatial access model we used, which adjusted for distance, size, and attractiveness. Finally, because of the exploratory nature of this social ecological study, chance cannot be ruled out as an explanation for some of the results, although our criteria for including variables in the final model were determined a priori. Notwithstanding these limitations, our study appears to be one of the few published investigations to include objectively measured physical environmental factors, and it provides some insights for future investigations.

CONCLUSIONS

Encouraging more walking has the potential to produce public health benefits, both for individuals and for the environment. However, few people engage in a sufficient amount of walking to benefit their health. Moreover, those who walk as well as do other physical activities appear more likely to achieve recommended levels of activity overall. Our results suggest that, if there are to be increases in walking among the general population, a comprehensive strategy must be in place that influences individuals as well as creates more supportive social and physical environments. Such a strategy will require a multilevel approach that involves both the health sector and transportation, planning, and local government agencies. ■

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Contributors

Both authors contributed to the design of the study and the development of survey instruments. B. Giles-Corti developed the environmental measures, analyzed the data, and wrote the article. R.J. Donovan contributed to the interpretation of the findings and to the writing and editing of the article.

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Human Participant Protection

This study was approved by the University of Western Australia human rights committee. Participation in the study was voluntary. Respondents were provided with information about the study and the length of time it would take to complete the questionnaire before they gave consent.

References

1. *Physical Activity and Health: A Report of the Surgeon General.* Atlanta, Ga: Centers for Disease Control and Prevention; 1996.
2. *Physical Activity Guidelines for All Australians: Scientific Background Report.* Canberra, Australian Capital Territory: Commonwealth Dept of Health and Family Services; 1998.
3. King AC, Blair SN, Bild DE, et al. Determinants of physical activity and interventions in adults. *Med Sci Sports Exerc.* 1992:24(suppl 6):S221–S236.
4. Bull F, Milligan R, Rosenberg M, MacGowan H. *Physical Activity Levels of Western Australian Adults 1999.* Perth, Western Australia: Health Dept of Western Australia; 2001.
5. Sallis JF, Bauman A, Pratt M. Environmental and policy interventions to promote physical activity. *Am J Prev Med.* 1998;15:379–397.
6. Owen N, Leslie E, Salmon J, Fotheringham MJ. Environmental determinants of physical activity and sedentary behavior. *Exerc Sport Sci Rev.* 2000;28:153–158.
7. Stahl T, Rutten A, Nutbeam D, et al. The importance of the social environment for a physically active lifestyle—results from an international study. *Soc Sci Med.* 2001;52:1–10.
8. Giles-Corti B, Donovan RJ. The relative influence of individual, social and physical environmental determinants of physical activity. *Soc Sci Med.* 2002;54(12):1793–1812.
9. Australian Bureau of Statistics. 1996 Census of Population Housing–Socioeconomic Indexes for Area, ABS Catalogue No 2039.0. Australian Bureau of Statistics, Canberra.
10. Giles-Corti B, Donovan R, Holman CJ. Factors influencing the use of physical activity facilities: results from qualitative research. *Health Promotion J Aust.* 1996;6(1):16–21.
11. Giles-Corti B, Donovan RJ, Castine RM, Holman CDJ, Shilton TR. Encouraging the sedentary to be active every day: qualitative formative research. *Health Promotion J Aust.* 1995;5(2):10–17.
12. Hansen WG. How accessibility shapes land use. *J Am Inst Plann.* 1959;15:73–76.
13. Bagozzi RP, Warshaw PR. Trying to consume. *J Consumer Res.* 1990;17:127–140.
14. Ajzen I. From intentions to action: a theory of planned behavior. In: Kuhl J, Beckman J, eds. *Action-Control: From Cognition to Behavior.* Heidelberg, Germany: Springer; 1985:11–39.
15. Bandura A. *Self-Efficacy: The Exercise of Control.* New York, NY: WH Freeman & Co; 1997.
16. Sallis JF, Hovell MF, Hofstetter CR, et al. Distance between home and exercise facilities related to frequency of exercise among San Diego residents. *Public Health Rep.* 1990;105:179–185.
17. Broomhall MH. *Study of the Availability and Environmental Quality of Urban Open Space Used for Physical Activity* [dissertation]. Perth, Western Australia: University of Western Australia; 1996.
18. Bauman A, Bellew B, Booth M, Hahn A, Stoker L, Thomas M. *NSW Health Promotion Survey 1994: Towards Best Practice for the Promotion of Physical Activity in the Areas of NSW.* Sydney, New South Wales, Australia: New South Wales Health Dept, Centre for Disease Prevention and Health; 1996.
19. *SPSS Base System: Syntax Reference Guide. Release 5.0.* Chicago, Ill: SPSS Inc; 1992.
20. Miettinen OS. Stratification by a multivariate confounder score. *Am J Epidemiol.* 1976;104:609–620.
21. Bull F. *The Role of General Practitioners in the Promotion of Physical Activity* [thesis]. Perth, Western Australia: University of Western Australia; 1997.
22. Beatley T. *Green Urbanism: Learning From European Cities.* Washington, DC: Island Press; 2000.
23. Stokols D. Establishing and maintaining healthy environments. *Am Psychol.* 1992;47:6–22.
24. Sallis JF, Owen N. Ecological models. In: Glanz K, Lewis FM, Rimer BK, eds. *Health Behavior and Health Education: Theory, Research, and Practice.* 2nd ed. San Francisco, Calif: Jossey-Bass Publishers; 1996:403–424.
25. Sallis JF, Owen N. *Physical Activity and Behavioral Medicine.* Thousand Oaks, Calif: Sage Publications; 1999.
26. Anderson W, Reid C, Jennings G. Pet ownership and risk factors for cardiovascular disease. *Med J Aust.* 1992;157:298–301.
27. Bauman AE, Russell SJ, Furber SE, Dobson AJ The epidemiology of dog walking: an unmet need for man and canine health. *Med J Aust.* 2001;175:632–634.
28. Environment, Transport and Regional Affairs Committee. *Walking in Towns and Cities: Memoranda Submitted to the Committee.* London, England: Stationery Office Ltd; 2001.
29. Giles-Corti B, Donovan RJ. SES differences in recreational PA levels and real and perceived access to a supportive physical environment. *Prev Med.* 2002:35: 601–611.
30. Ball K, Bauman A, Leslie E, Owen N. Perceived environmental aesthetics, convenience, and company are associated with walking for exercise in Australian adults. *Prev Med.* 2001;33:434–440.
31. Brownson RC, Baker EA, Housemann RA, Brennan LK, Bacak SJ. Environmental and policy determinants of physical activity in the United States. *Am J Public Health.* 2001;91:1995–2003.
32. Pikora T, Giles-Corti B, Bull F, Jamrozik K, Donovan R. Developing a framework for assessment of the environmental determinants of walking and cycling. *Soc Sci Med* 2003(56):1693–1703.
33. Pikora TJ, Bull FC, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable method to measure the physical environment for physical activity. *Am J Prev Med.* 2002:23(3):187–194.
34. Hamer L. *Making the Links: Integrating Sustainable Transport, Health and Environmental Policies. A Guide for Local Authorities and Health Authorities.* London, England: Health Education Authority; 1999.
35. Trewin D. *Australian Transport and the Environment.* Canberra, Australian Capital Territory: Commonwealth of Australia; 1997.
36. Pucher J, Lefevre C. *The Urban Transport Crisis in Europe and North America.* London, England: Macmillan; 1996.