Walking and Cycling to Health: A Comparative Analysis of City, State, and International Data

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Objectives. We sought to determine the magnitude, direction, and statistical significance of the relationship between active travel and rates of physical activity, obesity, and diabetes.

Methods. We examined aggregate cross-sectional health and travel data for 14 countries, all 50 US states, and 47 of the 50 largest US cities through graphical, correlation, and bivariate regression analysis on the country, state, and city levels.

Results. At all 3 geographic levels, we found statistically significant negative relationships between active travel and self-reported obesity. At the state and city levels, we found statistically significant positive relationships between active travel and physical activity and statistically significant negative relationships between active travel and diabetes.

Conclusions. Together with many other studies, our analysis provides evidence of the population-level health benefits of active travel. Policies on transport, land-use, and urban development should be designed to encourage walking and cycling for daily travel. (*Am J Public Health.* 2010;100:1986–1992. doi:10.2105/AJPH.2009.189324)

Many nations throughout the world have experienced large increases in obesity rates over the past 30 years.[1,2] The World Health Organization estimates that more than 300 million adults are obese,[3] putting them at increased risk for diseases such as diabetes, hypertension, cardiovascular disease, gout, gallstones, fatty liver, and some cancers.[4,5] Several studies have linked the increase in obesity rates to physical inactivity[6–8] and to widespread availability of inexpensive, calorie-dense foods and beverages.[1,9]

The importance of physical activity for public health is well established. A US Surgeon General's report in 1996, *Physical Activity and Health*,[10] summarized evidence from cross-sectional studies; prospective, longitudinal studies; and clinical investigations. The report concluded that physical inactivity contributes to increased risk of many chronic diseases and health conditions. Furthermore, the research suggested that even 30 minutes per day of moderate-intensity physical activity, if performed regularly, provides significant health benefits. Subsequent reports have supported these conclusions.[11–13]

The role of physical activity in prevention of weight gain is well documented.[14] Strong evidence from cross-sectional studies has established an inverse relationship between physical activity and body mass index.[15,16] In addition, longitudinal studies have shown that exercisers gain less weight than do their sedentary counterparts.[6,8] Thus, the obesity epidemic may be explained partly by declining levels of physical activity.[1,17,18]

A growing body of evidence suggests that differences in the built environment for physical activity (e.g., infrastructure for walking and cycling, availability of public transit, street connectivity, housing density, and mixed land use) influence the likelihood that people will use active transport for their daily travel.[19,20] People who live in areas that are more conducive to walking and cycling are more likely to engage in these forms of active transport.[21–25] Walking and cycling can provide valuable daily physical activity.[26–30] Such activities increase rates of caloric expenditure,[31] and they generally fall into the moderate-intensity range that provides health benefits.[32–35] Thus, travel behavior could have a major influence on health and longevity.[29,30,36,37]

Over the past decade, researchers have begun to identify linkages between active travel and public health.[38–40] Cross-sectional studies indicate that walking and cycling for transport are linked to better health. The degree of reliance on walking and cycling for daily travel differs greatly among countries.[39,41] European countries with high rates of walking and cycling have less obesity than do Australia and countries in North America that are highly car dependent.[26] In addition, walking and cycling for transport are directly related to improved health in older adults.[42] The Coronary Artery Risk Development in Young Adults Study found that active commuting was positively associated with aerobic fitness among men and women and inversely associated with body mass index, obesity, triglyceride levels, resting blood pressure, and fasting insulin among men.[26,39,41,43]

Further evidence of the link between active commuting and health comes from prospective, longitudinal studies.[44] Matthews et al. examined more than 67 000 Chinese women in the Shanghai women's health study and followed them for an average of 5.7 years.[37] Women who walked ($P<.07$) and cycled ($P<.05$) for transport had lower rates of all-cause mortality than did those who did not engage in such behaviors. Similarly, Andersen et al. observed that cycling to work decreased mortality rates by 40% among Danish men and women.[36] A recent analysis of a multifaceted cycling demonstration project in Odense, Denmark, reported a 20% increase in cycling levels from 1996 to 2002 and a 5-month increase in life expectancy for males.[45]

We analyzed recent evidence from a variety of data sources that supports the crucial relationship between active travel, physical activity, obesity, and diabetes. We used city- and state-level data from the United States and national aggregate data for 14 countries to determine the magnitude, direction, and statistical significance of each relationship.

METHODS

We derived data for international comparisons of obesity from published studies of health interview and health examination surveys from

2000 to 2006.[26] Health interview studies rely on self-reported measures of height and body weight, and health examination surveys use clinical measurements of those variables. In all of these studies, obesity was defined as a body mass index (defined as weight in kilograms divided by height in meters squared) of 30 kg/m^2 or higher.

Data on physical activity, obesity, and diabetes for US states and metropolitan areas came from the Behavioral Risk Factor Surveillance System (BRFSS).[46] BRFSS relies on random-digit-dialed telephone surveys that collect information on health risk behaviors, preventive health practices, and health care access. BRFSS surveys are administered annually to US civilian noninstitutionalized adults aged 18 years or older. Our state-level data came from the 2007 BRFSS survey (n=430 912). We obtained information for the metropolitan areas from the 2007 BRFSS Selected Metropolitan/Micropolitan Area Risk Trends (SMART) data, a subset of BRFSS with data from metropolitan-area samples of 500 or more respondents. The BFRSS data for cities included each city's surrounding county or metropolitan area and thus were not exact matches for the cities themselves. BFRSS data were not available in 2007 for 3 of the 50 largest US cities; we therefore included only 47 cities in our statistical models.

All BRFSS data are self-reported, and the Council of American Survey Research Organizations method median response rate for the 2007 survey was 51%.[47] Respondents were queried on the amount of time spent in moderate and vigorous physical activity, walking, and sitting.[48] Meeting physical activity recommendations was defined for adults as 30 minutes or more of moderate physical activity 5 or more days per week or vigorous physical activity for 20 minutes or more 3 or more days per week.[12] As in many international studies, BRFSS defined obesity as a body mass index of 30 kg/m^2 or higher. Diabetes was considered to be present if respondents reported ever having been told by a health care professional that they had the condition.

We derived data on walking and cycling levels for different countries from national travel surveys, which typically use a 1-day travel diary in which individuals keep a record of the purpose of their trip, destination, trip distance, starting and ending times, and mode of travel.[49] For our international comparison, we analyzed data for 2000–2006 from 14 countries on 3 continents: Australia, Canada, Denmark, Finland, France, Germany, Ireland, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and the United States.[26,50] These survey data covered trips for all purposes, except the Canadian and Australian surveys, which were limited to work trips.

Data on active travel for individual US states and cities came from the 2007 American Community Survey (ACS), which reported the share of workers commuting by bicycle or foot.[51] ACS is the only study that reports comparable year-round travel data for cities and states in the United States. Every year, the US Census Bureau collects ACS data by phone or mail or in person from a random sample of 2 million housing units and group quarters. As with the decennial census, participation in the ACS is required by law—which helps explain a response rate of 98% for 2007. The survey asks respondents to indicate their usual mode of transport to work—excluding modes used only occasionally or for short portions of a trip combined with longer segments traveled by automobile or public transport.[51] Moreover, ACS reports only on work commutes and thus underestimates the total level of walking and cycling.

To examine the relationships between active travel and health-related variables, we used graphical, bivariate correlation, and regression analyses between various pairings of variables. We used the same procedure for each of the 3 geographic levels—international, state, and city. Before analyzing bivariate relationships, we first examined the distributions of each variable to detect outliers and potentially skewed distributions. We then plotted the bicycle and walk shares against individual health indicator variables to detect the mathematical form of the relationship and eventually determined that a nonlinear curve would be most appropriate. (Summary statistics and detailed listings of data values of all variables for individual countries, states, and cities are shown in Tables A–C, available as a supplement to the online version of this article at http://www.ajph.org).

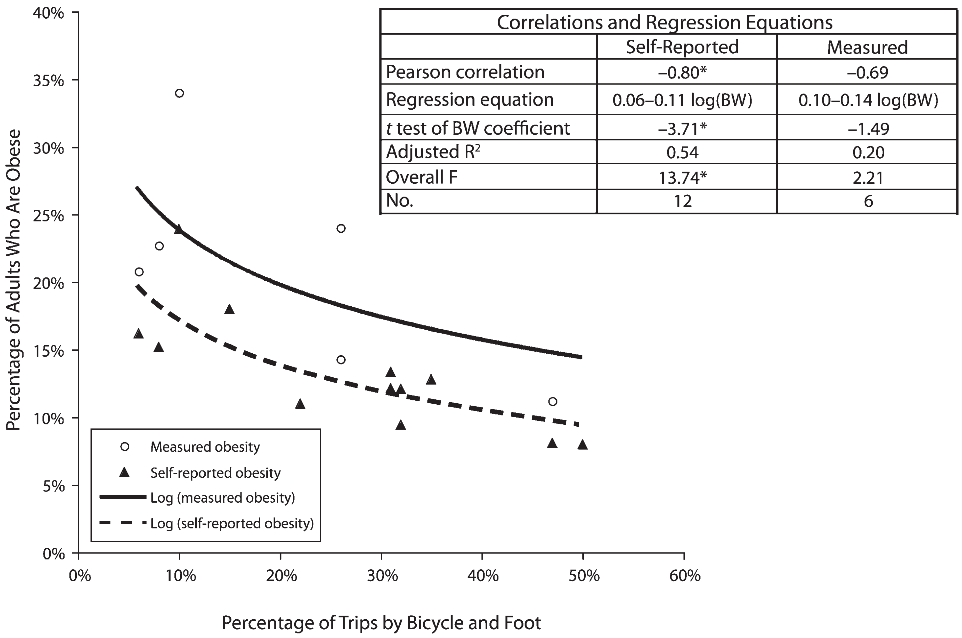
Bivariate correlation analysis revealed the magnitude, direction, and statistical significance of the paired relationships. We then estimated bivariate log-linear regressions to examine the hypothesis that active transport was associated with the health variables. For each of the regressions, we reported the statistical significance of the coefficient for active transport as well as the statistical significance of the overall model and the percentage of variance in the health indicator explained by variation in active transport rates.

RESULTS

Figures 1 to 4 present the results of our statistical analysis of the relationships between active travel and various health indices at 3 geographic levels. In each figure, active travel is shown on the horizontal axis, and the health indices are shown on the vertical axis. Each graph shows all of the individual data observations as well as the estimated bivariate nonlinear regression curve that minimizes the sum of squared deviations from the data points. The associated Pearson correlation coefficient, bivariate regression equation, sample size, measures of goodness of fit, and statistical tests of significance (R^2, t, F) can be found in a box inserted into the corner of each figure.

Figure 1 portrays the relationship between the share of trips by cycling and walking (all trip purposes) and the percentage of adults who were obese in the 14 countries we studied. Figure 1 shows national obesity rates derived from surveys of self-reported height and weight for 12 countries and from clinically measured height and weight for 6 countries. Consistent with results from all previous studies, self-reported obesity rates were lower than clinically measured rates.

Whether self-reported or clinically measured, obesity rates were inversely related to shares of trips by walking and cycling in the 14 countries. The national travel and health surveys drew on large samples, but our use of the national averages for the correlations shown in Figure 1 limited the number of observations. The larger group of 12 countries with self-reported obesity rates yielded a Pearson correlation coefficient, bivariate coefficient estimate (for the bike+walk variable), and overall F statistic for the equation that were statistically significant ($P<.01$). The corresponding equation for measured obesity rates relied on far too small a sample to yield statistically significant estimates, but the coefficient signs



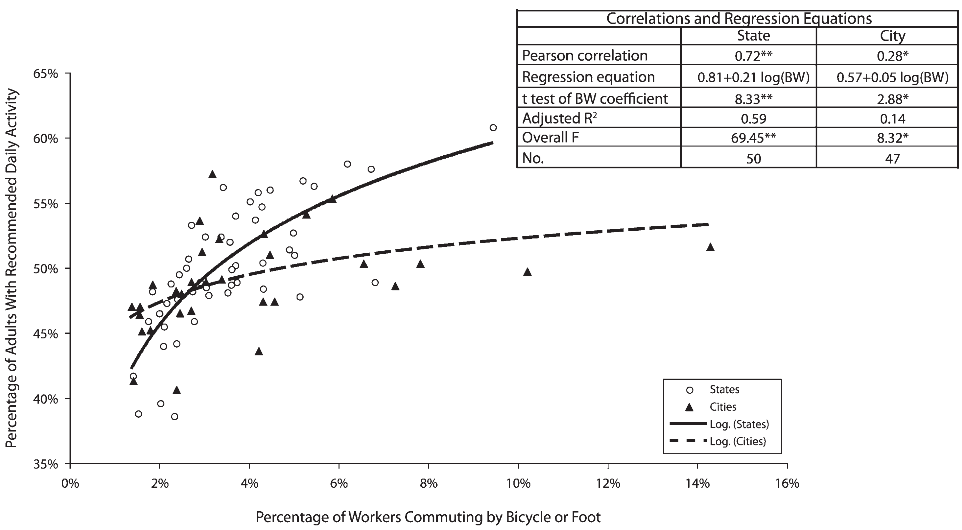
Correlations and Regression Equations		
	Self-Reported	Measured
Pearson correlation	–0.80*	–0.69
Regression equation	0.06–0.11 log(BW)	0.10–0.14 log(BW)
t test of BW coefficient	–3.71*	–1.49
Adjusted R^2	0.54	0.20
Overall F	13.74*	2.21
No.	12	6

Note. BW = bicycle + walk.
Source. Data from Bassett et al.[26]
*P < .01; **P < .001.

FIGURE 1—Relationship between adult obesity and active transport in Australia and 13 countries in Europe and North America: 2000–2006.

were in the expected direction. Neither of the equations in Figure 1 proved a causal relationship between active transport and obesity levels at the population level, but the results were consistent with such a relationship.

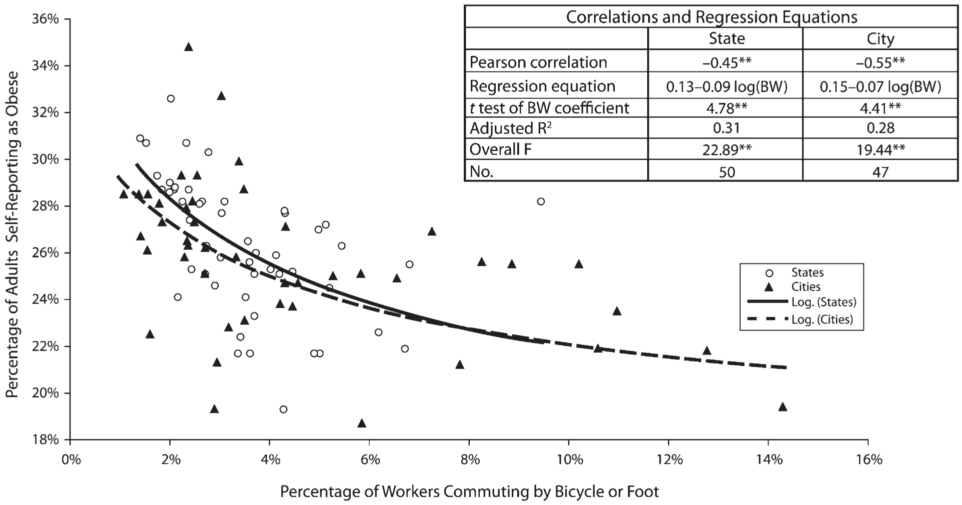
Figures 2, 3, and 4 display the results of our analysis of active travel and health data for all 50 US states and 47 of the 50 largest US cities. The travel data in these figures include only cycling and walking trips to work by adults, as reported by the 2007 ACS.[51]



Correlations and Regression Equations		
	State	City
Pearson correlation	0.72**	0.28*
Regression equation	0.81+0.21 log(BW)	0.57+0.05 log(BW)
t test of BW coefficient	8.33**	2.88*
Adjusted R^2	0.59	0.14
Overall F	69.45**	8.32*
No.	50	47

Note. BW = bicycle + walk.
Source. Data from the Centers for Disease Control and Prevention[46] and the US Census Bureau.[51]
*P < .01; **P < .001.

FIGURE 2—Relationship between share of workers commuting by bicycle or foot and share of adults with levels of physical activity recommended by the Centers for Disease Control and Prevention: 50 US states and 47 of the 50 largest US cities, 2007.

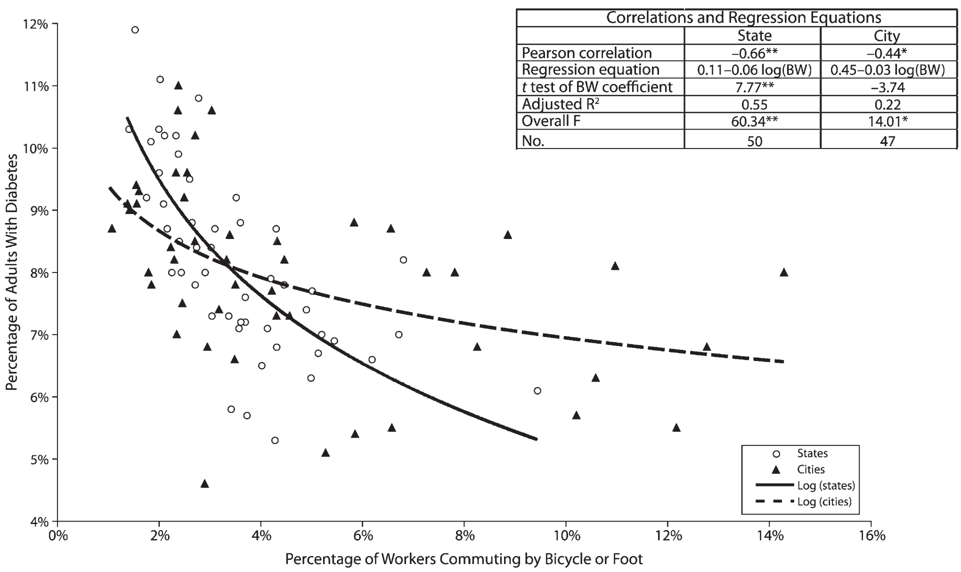


Correlations and Regression Equations		
	State	City
Pearson correlation	–0.45**	–0.55**
Regression equation	0.13–0.09 log(BW)	0.15–0.07 log(BW)
t test of BW coefficient	4.78**	4.41**
Adjusted R^2	0.31	0.28
Overall F	22.89**	19.44**
No.	50	47

Note. BW = bicycle + walk.
Source. Data from the Centers for Disease Control and Prevention[46] and the US Census Bureau.[51]
*P < .01; **P < .001.

FIGURE 3—Relationship between share of workers commuting by bicycle or foot and self-reported obesity levels: 50 US States and 47 of the 50 largest US cities, 2007.

Figure 2 illustrates the relationship between overall physical activity levels and the share of workers cycling and walking to work in US states and cities. Both at the state and city levels, we observed a positive relationship between active commuting to work and the percentage of adults attaining the weekly level of physical activity recommended by the Centers for Disease Control and Prevention. The Pearson correlation coefficient was larger and more statistically significant at the state (Pearson r=0.72; P<.001) than at the city (Pearson r=0.28; P<.01) level. Variation in the bike + walk share accounted for 59% of the variation in the physical activity share at the



Correlations and Regression Equations		
	State	City
Pearson correlation	–0.66**	–0.44*
Regression equation	0.11–0.06 log(BW)	0.45–0.03 log(BW)
t test of BW coefficient	7.77**	–3.74
Adjusted R^2	0.55	0.22
Overall F	60.34**	14.01*
No.	50	47

Note. BW = bicycle + walk.
Source. Data from the Centers for Disease Control and Prevention[46] and the US Census Bureau.[51]
*P < .01; **P < .001.

FIGURE 4—Relationship between share of workers commuting by bicycle or foot and share of population with diabetes: 50 US States and 47 of the 50 largest US cities, 2007.

state level and for only 14% at the city level. Similarly, the bivariate regression overall as well as the bike+walk variable coefficient were more significant at the state ($P<.001$) than at the city ($P<.01$) level.

The larger size and greater statistical significance of the relationships at the state level may be partly attributable to greater aggregation and thus less variation at the state level compared with the city level. Moreover, the BRFSS health data shown for cities in Figures 2, 3, and 4 actually referred to their counties or metropolitan areas and thus were not exact matches for the cities themselves.

Figure 3 shows the relationship between the share of US adults who were obese (according to self-reported height and weight) and the percentage of survey respondents walking or cycling to work. Both the state and city data suggest a strong negative relationship, with Pearson correlation coefficients of –0.45 and –0.55, respectively (both statistically significant at $P<.001$). States and cities with high shares of cycling and walking commuters tended to have lower rates of self-reported obesity. The bivariate equations overall as well as the bike+walk variable coefficients were highly significant for both state and city data ($P<.001$). Variation in the bike+walk share was estimated to account for 31% of the variation in adult obesity rates among states and 28% of the variation among cities.

Figure 4 illustrates the relationship between active commuting and rates of diabetes in US states and cities. At the state level, we found a strong and statistically significant inverse relationship between walking and cycling to work and diabetes (Pearson $r=-0.66$; $P<.001$). The share of adults with diabetes was much lower for states with higher shares of active commuters. The bivariate regression equation reported in Figure 4 was also highly significant. More than half of the variation in diabetes rates among states was accounted for by variation in bike–walk commute rates. The relationship at the city level was in the same direction but weaker (Pearson $r=-0.44$; $P<.01$). Although the overall F statistic and t statistic indicated statistical significance at the 99% level ($P<.01$), the model accounted for only 22% of the variation in diabetes rates among cities, less than half of the explanatory power of the model at the state level.

DISCUSSION

Our results suggest statistically significant relationships—in the expected direction—between walking, cycling, and health at the country, state, and city levels. Among the 14 countries in our international comparison, those with higher levels of walking and cycling tended to have lower levels of adult obesity, whether self-reported or clinically measured. In our comparison of all 50 US states and 47 of the largest 50 US cities, we found that higher rates of walking and cycling to work were associated with (1) a higher percentage of adults who achieved recommended levels of physical activity, (2) a lower percentage of adults with obesity, and (3) a lower percentage of adults with diabetes. The results of our graphical, correlation, and bivariate regression analysis did not prove causality but were consistent with the hypothesis that active travel encourages more physical activity and leads to lower rates of obesity and diabetes.

Perhaps the greatest strength of our analysis was that it showed that the relationship between active travel and health was discernible at 3 different geographic levels: international, state, and city. Our inclusion of Australia and of both European and North American countries increased the range of observed active travel rates (6%–50% among countries, 2%–9% among US states, and 1%–14% among US cities). The cycling and walking shares of trips in some European countries were 3 to 5 times as high as the shares in any US state. Similarly, the international comparison expanded the range of self-reported obesity rates (8%–24% among countries, 19%–33% among US states, and 19%–35% among US cities).

Limitations

Because it was cross-sectional, our study could not assess the health effects of changing rates of active travel over time. Moreover, the analysis relied on aggregated population-level data. The analysis suggested a statistically significant relationship between active travel and health at the population level, but such ecological analysis did not permit us to draw conclusions about the health effects of active travel for individuals. From a public health policy perspective, such a shortcoming may not be serious because the intent of policy is to improve health outcomes at the population level by adopting society-wide interventions. For example, a policy goal may be to increase physical activity for the overall population; our results suggest that promoting walking and cycling for daily travel could be an effective approach.

Another limitation of our analysis was the inability to control for other factors affecting physical activity levels, obesity, and diabetes. In particular, no comparable city, state, and international data on nutrition (e.g., caloric intake) or genetics (e.g., family medical history) were available for inclusion in the analysis. Finally, small sample sizes and unavailability of data for control variables restricted the statistical analysis to graphs, correlations, and bivariate regressions. In an analysis of only 47 US cities, 50 US states, and 14 countries, incorporating many control variables would have been difficult, even if the data were available. Our results should therefore be interpreted with caution.

Conclusions

Our results suggest a significant relationship between walking, cycling, and health, but the results are not sufficient to prove that such a relationship exists or that active transport causes improved health. However, our results should be viewed not in isolation but as part of a mounting body of evidence on the health benefits of active travel.[29,52–56]

Whatever the shortcomings of the aggregate analysis in this paper, the analysis benefited from a broad geographic scope and 3 different geographic levels of analysis. At national, state, and city levels, we found statistically significant negative relationships between active travel and self-reported obesity. At the state and city levels, we found statistically significant positive relationships between active travel and physical activity and statistically significant negative relationships between active travel and diabetes.

These findings reinforce the need for US cities to encourage more walking and cycling for daily travel. This encouragement requires the provision of safe, convenient, and attractive infrastructure, such as sidewalks, crosswalks, bike paths and lanes, and intersection modifications that protect pedestrians and cyclists.[20,21,39,50,52,56–59] Such cycling and walking infrastructure improvements should be combined with restrictions on car use, such as car-free zones, traffic calming in residential neighborhoods, reductions in motor vehicle speeds, and limited and more expensive car parking.[19–21,60] Moreover, land-use policies should foster compact, mixed-use developments that generate shorter trip distances that are easier to cover by walking and cycling.[19,27,39,52,57] Government transport and land-use policies explain much of the large gap in active transport rates between Europe and North America.[22,26,39,41,61,62] Improving those policies will be essential to increasing walking and cycling levels in the United States.[56,62–64] ■

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***Note.** The findings and conclusions in this article are those of the authors and do not necessarily represent the views of the Centers for Disease Control and Prevention.*

Contributors

J. Pucher led the writing of the article. J. Pucher and R. Buehler had primary responsibility for study design, data collection and analysis, and creation of the graphs and tables. D.R. Bassett and A.L. Dannenberg reviewed the public health literature. All authors helped to interpret findings and review drafts of the article.

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Human Participant Protection

No protocol approval was required because the study relied entirely on secondary, aggregate data from national surveys.

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