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Relationship between the built environment and physical activity levels: The Harvard Alumni Health Study

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Abstract

Background—Physical activity is associated with better health, but many individuals are insufficiently active. Modifying the built environment may be an approach capable of influencing population-wide levels of physical activity, but few data exist from longitudinal studies that can minimize bias from active persons choosing activity-friendly neighborhoods. This is the first large-scale study to examine longitudinal changes in the built environment and physical activity.

Methods—This study examined cross-sectional associations between urban sprawl (mapping addresses to corresponding counties) and physical activity (self-reported) among men throughout the US in 1993 and in 1988, and longitudinal associations between changes in exposure to urban sprawl for movers and physical activity, 1988–1993. Included were 4,997 men (mean age, 70 years) in the 1993 cross-sectional study; 4,918 men in the 1988 cross-sectional study; and 3,448 men in the longitudinal study, 1988–1993. Data were collected prospectively in 1988 and 1993, and analyses were performed in 2007–2008.

Results—In cross-sectional analyses, less sprawl was significantly associated with more walking (odds ratios (OR), comparing least with most sprawling areas, for meeting physical activity recommendations by walking = 1.38 [95% confidence interval = 1.09, 1.76] in 1993 and 1.53 [1.19, 1.96] in 1988). Less sprawl also was associated with lower prevalence of overweight (corresponding OR = 0.79 [0.64, 0.98] in 1993 and 0.81 [0.66–1.00] in 1988). However, longitudinal analyses assessing change did not show that decreasing sprawl was associated with increased physical activity or decreased body mass index.

Conclusions—These findings suggest that the cross-sectional results may reflect self-selection, rather than indicating that the built environment – as measured by urban sprawl – increases physical activity. However, the longitudinal findings were limited by small numbers of men changing residence and associated sprawl levels.

INTRODUCTION

There is abundant research linking physical activity with better health, in part because of its relation with less overweight,^{1–3} yet many Americans are insufficiently active.^{4,5} Thus, developing effective methods to increase physical activity is a public health priority. Behavioral approaches targeting the individual can work^{6,7} but have limited impact. Recently, there has been interest in population-wide approaches that potentially affect many individuals simultaneously, such as modifying the built environment.^{8–12}

Research into whether the built environment (land use patterns, transportation systems, and design features) can influence physical activity poses unique methodological challenges.^{13, 14} In 2005, the National Research Council concluded that the available data indicate a link between the built environment and physical activity; however, because almost all data were from cross-sectional studies, “this single source of potential bias casts doubt on the majority of studies on this topic to date”.¹⁵ That is, do the findings merely reflect the choice of active individuals to live in neighborhoods conducive to physical activity? One recommendation was to conduct further research using longitudinal study designs to minimize self-selection bias. A 2008 national meeting of experts also declared “prospective studies and evaluations of natural experiments to improve evidence of causality” to be the top-ranked research priority.¹⁶

Thus, this study investigated both cross-sectional and longitudinal associations between the built environment and physical activity, hypothesizing that certain features of the built environment would be associated with higher activity levels.

METHODS

Study Population

The Harvard Alumni Health Study is an ongoing study of men matriculating as undergraduates at Harvard University, 1916- 1950,¹⁷ approved by the institutional review board of the Harvard School of Public Health. Since 1962, alumni have periodically returned mailed health questionnaires. Address information remained available for men returning questionnaires in 1988, 1993, and 1998, and physical activity was ascertained identically in 1988 and 1993, but abbreviated data were collected in 1998. Thus, analyses were limited to men returning the 1988 and 1993 questionnaires, to avoid changes due to differences in physical activity questions.

A computerized tape containing addresses for the 1993, but not 1988, mailing remained available, so cross-sectional analyses first focused on 1993 data. The 1988 addresses of participants who also returned a 1993 questionnaire were entered into a computerized database.

Assessment of Urban Sprawl

Currently, the predominant metropolitan development pattern in the US is one characterized as urban sprawl.⁸ Poor accessibility is the common feature of sprawling areas. People living in sprawling areas drive more for transport; people living in compact communities walk more.⁸ This characteristic – degree of urban sprawl – was chosen to investigate whether the built environment can influence physical activity.

For each participant, his mailing addresses in 1993 and 1988 were matched to the corresponding counties, using commercial software (<http://www.semaphorecorp.com>). Based on the county, a sprawl index was assigned to the participant at each time. The index was developed in 1990 and 2000 by urban planners,^{8,18-21} and considers gross population density, percent living at low and at high densities, county population per square mile of urban land, average block size, and percent of blocks 500 feet or smaller on a side (a traditional block size). For this study, the 1990 index was used, 1990 being closest to the years under study. The index is scaled to a mean of 100 and standard deviation (SD) of 25, across all counties. The larger the value, the more compact, or less sprawling, is the county. This index has demonstrated cross-sectional, direct associations with walking, and inverse associations with body mass index and prevalence of chronic medical conditions in previous studies.^{18,22-25} Data were available on the input variables to calculate sprawl indices for 448 counties, covering two-thirds of the US population.

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Assessment of Physical Activity and Health Outcomes

On the 1993 and 1988 questionnaires, men reported their daily walking and stair climbing, sports and recreational activities in the past week, and the frequency and duration of participation.²⁶ This assessment of physical activity has been shown to be reliable and valid.²⁷⁻³⁰ Men also reported smoking habits, weight and height, diet (1988 only) and physician-diagnosed hypertension, high cholesterol, and diabetes.

Statistical Analyses

Cross-sectional analyses—The main exposure was county level of urban sprawl. Four categories were initially defined: <75, 75-99, 100-124, and ≥ 125 ; however, the distribution was skewed and so this was collapsed into three categories prior to additional analyses: <100 (most sprawling), 100-124, and ≥ 125 (least sprawling). The main outcome was whether men met physical activity recommendations (equivalent to ≥ 150 min/week moderate-intensity activity¹) (a) based on all activities reported, and (b) based on walking alone.

Logistic regression³¹ analyzed the associations between urban sprawl and physical activity, adjusted for age and smoking (never, past, or current). Similar analyses examined the associations of urban sprawl with the prevalence of overweight (body mass index, BMI, ≥ 25 kg/m²), and these secondary outcomes: physician-diagnosed hypertension, high cholesterol, and diabetes. In additional analyses, further adjustment was made for diet in 1988. The results did not differ materially from those where diet was not considered, and so findings unadjusted for diet are presented.

Longitudinal analyses—For these analyses, participants were grouped according to three levels of change in urban sprawl between 1988 and 1993: moved to a more sprawling area (i.e., value of sprawl index increased between 1988 and 1993), no change, or moved to a less sprawling area. Linear regression³² estimated the mean change in energy expended on all activities from 1988 to 1993, adjusted for age, smoking, and baseline (1988) energy expenditure. Parallel analyses examined changes in distance walked and BMI.

Analyses were conducted in 2007-2008 using SAS release 9.1.3.

RESULTS

Cross-sectional Analyses, 1993

Eligible were 11,894 men who returned a health questionnaire; 9,816 possessed addresses matched to a county by the matching program, and 7,629 (64%) resided in counties with available urban sprawl indices. Then 34 men with missing physical activity data and 2,598 men with cardiovascular disease and cancer (to prevent bias from decreased activity due to disease) were excluded, leaving 4,997 men. These 4,997 men, compared with those excluded because urban sprawl indices were unavailable, were generally similar (e.g., mean age, 70 and 70 years, respectively; BMI, 24.9 and 24.9 kg/m²; physical activity, 2,453 and 2,715 kcal/week; smokers, 5.8% and 5.8%).

Table 1 shows 11% resided in counties considered most sprawling; 26%, in counties considered least sprawling. The mean age of men was 70.0 years. Men living in least sprawling areas tended to be younger, leaner, more physically active, and have lower prevalence of hypertension, but greater prevalence of high cholesterol. Men in the middle sprawl category were least likely to smoke, while the prevalence of diabetes did not differ across sprawl categories.

In analyses adjusted for age and smoking (Table 2), while there was no significant association between urban sprawl and the odds of meeting physical activity recommendations through any activity, men in least sprawling counties had a 38% higher odds of walking sufficiently to meet recommendations, compared with those in most sprawling counties. They also had a 21% lower odds of being overweight, and a 24% lower odds of hypertension. There were no significant associations with prevalence of high cholesterol or diabetes.

Cross-sectional Analyses, 1988

Eligible were 9,555 men returning a health questionnaire in both 1988 and 1993 were eligible; 8,308 had addresses that could be matched to a county, and 6,732 (70%) resided in counties with available urban sprawl indices. Then 257 men with missing physical activity data and 1,557 men with cardiovascular disease and cancer were excluded, leaving 4,918 men.

The distribution of characteristics according to urban sprawl in 1988 was similar to that observed in 1993 (data not shown). Generally similar associations were observed as for 1993 (Table 2).

Longitudinal Analyses, 1988-1993

Included were 3,448 men with addresses that could be mapped in 1988 and 1993 to counties with sprawl indices. Included men possessed similar characteristics to those excluded.

In these analyses, only 3.9% of men moved to a more sprawling county, and 2.1% to a less sprawling county (Table 3). When comparing change in the mean energy expended on all activities, adjusted for age, smoking, and baseline energy expenditure, there were no significant differences among men in the three categories of move. There also were no significant differences in the change in walking among the three groups. For change in BMI, men moving to less sprawling areas actually gained significantly more weight, compared to those retaining the same sprawl levels. Additional adjustment for hypertension, high cholesterol, and diabetes did not change results (data not shown).

DISCUSSION

In this study, cross-sectional analyses support an association between less urban sprawl and more walking, as well as lower prevalence of overweight and hypertension. But in longitudinal analyses, men moving from more to less sprawling counties did not increase their walking or lower BMI. These observations suggest that the cross-sectional findings may reflect selection bias (i.e., active individuals choose neighborhoods conducive to physical activity), rather than indicating that the built environment – at least, as measured by urban sprawl – increases physical activity. However, the longitudinal analyses were limited by small numbers of men moving from more to less sprawling counties, and vice versa.

The hypothesis that physical activity can be influenced on a large scale by modifying the environment is attractive and plausible. A parallel may be drawn with tobacco control, where environmental and public health policies have decreased smoking levels more than individual interventions.³³ In designing urban areas, land use and transportation planners have long considered how design affects human behavior, primarily in relation to costs and benefits.⁸ More than 50 studies in this field have examined the built environment and utilitarian travel;⁸ walking and bicycling for transportation were consistently associated with less sprawling communities.³⁴ In the public health literature, several studies also have reported similar associations.^{35,36}

The primary limitation of existing studies is that they are almost exclusively cross-sectional.^{9,12} This study design cannot differentiate whether the environment influences physical activity

(“environmental determinism”³⁷), or whether active individuals choose activity-friendly neighborhoods (self-selection). A recent study reported that persons preferring, and living in, walkable neighborhoods walked more (34%) and drove less (26 miles/day) than those preferring, and living in, car-dependent neighborhoods (3% walked; 43 miles/day driven).³⁸ Cross-sectional studies which adjust for residential preferences continue to show an association between walkable neighborhoods and more walking.^{38,39}

Limited data are available from longitudinal studies, which can mitigate self-selection bias. Environmental changes in a San Diego naval air station were associated with improvements in the fitness of active-duty personnel,⁴⁰ while improved lighting on three urban London streets,⁴¹ and improved bicycle paths on six streets in Toronto⁴² were associated with more persons walking and greater bicycle traffic.

For body weight, cross-sectional studies also consistently show significant associations with the built environment,⁴³ but few longitudinal data exist. The 1997 US National Longitudinal Study of Youth (NLSY) observed findings similar to the present study: significant cross-sectional associations between more sprawl and higher BMI, but no significant association between changes in sprawl and BMI in longitudinal analyses.²³ However, another study of 262 men and women who originally participated in the 1979 NLSY reported a significant association between moving to less sprawling counties and decreased BMI.²⁰ This study also indicated some self-selection: persons with lower BMI were more likely to move to less sprawling counties.²⁰

A further limitation is that many studies have relied on subjects’ perception of their physical environment.³⁶ Active persons may be more aware of exercise facilities, or they may be more willing to walk further to their destinations. Studies comparing subjects’ perceptions with objective data derived from geographic information system (GIS) technology indicate low to fair agreement, with the highest agreement among regularly active subjects.^{44,45} This could bias findings towards an association between activity-friendly environments and physical activity levels.

The major strengths of this study are its large size, longitudinal design, and objective and validated measures of the built environment. It also possessed validated and detailed measures of physical activity, and a homogenous population, which minimizes confounding by socioeconomic status and race.

Limitations include, in particular, few men changing urban sprawl levels over time. However, even disregarding statistical significance, the point estimates do not support the hypothesis that less sprawl increases physical activity – men moving to less sprawling areas showed point estimates of decreased physical activity. And, congruent with this, these men significantly increased their BMI, compared to men with unchanged sprawl levels. Because of small numbers, we could not meaningfully examine changes in the proportions meeting physical activity recommendations between 1988 and 1993 with corresponding changes in urban sprawl. Second, the assessment of sprawl may have been too imprecise – counties are large geographic areas – to observe an association. However, expected associations were observed in cross-sectional analyses; thus, the measure of sprawl was at least precise enough for these analyses. Third, finer features of the built environment (e.g., streetlights, traffic, etc.) were not assessed; nonetheless, this study still provides important information for a “macro” level of the built environment.

Fourth, occupational physical activity was not assessed; however, Harvard alumni likely had white-collar jobs involving primarily walking and stair-climbing, which were assessed. Additionally, walking for exercise versus travel, which is more likely to be influenced by the environment,^{8,12} was not differentiated. This, however, unlikely caused a major bias because

expected associations between urban sprawl and overall walking were observed in cross-sectional analyses. Fifth, the reasons for, and timing of, moves to a new residence were not ascertained. Moves may have occurred because of ill-health, and a short duration at the new residence may be insufficient for change in physical activity to occur. Finally, while the homogeneity of the population limits generalizability to other groups; younger men may have a wider range of activity, allowing for better detection of any differences, and their behavior also may be more strongly influenced by the environment.⁴⁶

In conclusion, the longitudinal data from this study do not support the hypothesis that the built environment, as measured by county-level urban sprawl, can increase physical activity; however, statistical power was limited. More research is needed before dedicating vast sums of money to urban redesign with the sole intention of increasing physical activity. Studies of longitudinal design among diverse populations, with adequate sample sizes among persons who move, and which employ objective and precise characterizations of the built environment, are needed.

This is report No. XC in a series on chronic disease in former college students.

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Table 1Characteristics of men according to urban sprawl level^a in 1993

Characteristic	High sprawl (n = 551)	Medium sprawl (n = 3,126)	Low sprawl (n = 1,320)
Mean age (SD) (years)	70.5 (6.8)	70.2 (7.3)	69.4 (7.1)
% overweight ^b	46.8	46.7	43.2
% current smokers	6.4	5.6	6.2
Mean energy expended on all activities (SD) (kcal/week)	2,561 (2,772)	2,449 (2,589)	2,420 (2,677)
Mean distance walked (SD) (miles/week)	6.2 (7.0)	6.2 (6.9)	7.8 (7.9)
% meeting physical activity recommendations, based on all activities ^c	66.2	68.0	69.8
% walking sufficiently to meet physical activity recommendations ^c	22.0	22.6	28.4
% with hypertension	31.2	28.6	25.4
% with high cholesterol	23.5	26.0	26.9
% with diabetes	4.2	4.0	4.3

^aHigh sprawl category includes counties with sprawl index <100 (least compact), medium sprawl category includes counties with sprawl index 100-124, low sprawl category includes counties with sprawl index ≥125 (most compact). The larger the index, the less sprawling (more compact) is the neighborhood.

^bBody mass index ≥25 kg/m².

^cAccording to current recommendations.¹

Table 2

Odds ratios^a (95% confidence intervals) for meeting physical activity recommendations and for various health outcomes according to urban sprawl level, in cross-sectional analyses

Outcome	Cross-sectional analyses, 1993			
	High sprawl (n = 551)	Medium sprawl (n = 3,126)	Low sprawl (n = 1,320)	p, trend
Meets recommendations, based on all activities ^b	1.00	1.02 (0.84-1.25)	1.10 (0.88-1.37)	0.30
Walks sufficiently to meet recommendations ^b	1.00	1.02 (0.81-1.27)	1.38 (1.09-1.76)	<0.001
Overweight ^c	1.00	0.97 (0.80-1.17)	0.79 (0.64-0.98)	0.003
Hypertension	1.00	0.89 (0.73-1.08)	0.76 (0.61-0.95)	0.01
High cholesterol	1.00	1.15 (0.92-1.42)	1.15 (0.90-1.45)	0.53
Diabetes	1.00	0.94 (0.59-1.50)	1.05 (0.63-1.75)	0.61

Outcome	Cross-sectional analyses, 1988			
	High sprawl (n = 497)	Medium sprawl (n = 3,042)	Low sprawl (n = 1,379)	p, trend
Meets recommendations, based on all activities ^b	1.00	0.93 (0.75-1.14)	1.15 (0.92-1.45)	0.01
Walks sufficiently to meet recommendations ^b	1.00	1.01 (0.80-1.28)	1.53 (1.19-1.96)	<0.001
Overweight ^c	1.00	0.91 (0.75-1.10)	0.81 (0.66-1.00)	0.04
Hypertension	1.00	0.86 (0.70-1.06)	0.76 (0.60-0.95)	0.02
High cholesterol	1.00	1.20 (0.93-1.55)	1.23 (0.94-1.62)	0.31
Diabetes	1.00	1.23 (0.75-2.04)	1.14 (0.66-1.97)	0.95

^a Adjusted for age and smoking.

^b According to current recommendations.¹

^c Body mass index ≥ 25 kg/m².

Table 3
Change in physical activity and body mass index according to change in urban sprawl level, 1988-1993

Change in outcome, ^b 1988-1993	Moved to more sprawling county (n = 135)	Remained at same sprawl (n = 3,240)	Moved to less sprawling county (n = 73)
Change in mean energy expended on all activities (kcal/week)	230 (208)	-76 (42)	-157 (283)
Change in mean distance walked (miles/week)	0.08 (0.5)	0.03 (0.1)	-0.6 (0.7)
Change in mean body mass index (kg/m ²)	-0.10 (0.13)	0.08 (0.03)	0.47 (0.17) ^b

^a Adjusted least-squares mean (standard error). Values are adjusted for age, smoking, and baseline values.

^b p<0.05, compared to remaining at same sprawl.