Published in final edited form as:
Am J Prev Med. 2008 July ; 35(1): 38–46.

Built Environment, Adiposity, and Physical Activity in Adults Aged 50–75

Fuzhong Li, PhD, **Peter A. Harmer, PhD, MPH**, **Bradley J. Cardinal, PhD**, **Mark Bosworth, MS**, **Alan Acock, PhD**, **Deborah Johnson-Shelton, PhD**, and **Jane M. Moore, PhD**
From the Oregon Research Institute (Li, Johnson-Shelton), Eugene; Willamette University (Harmer), Salem; Oregon State University (Cardinal, Acock), Corvallis; Metro Regional Services (Bosworth) and the Department of Human Services (Moore), Oregon Health Division, Portland, Oregon

Abstract

Background—Few studies have investigated the built environment and its association with health—especially excess adiposity—and physical activity in the immediate pre-Baby Boom/early-Baby Boom generations, soon to be the dominant demographic in the U.S. The purpose of this study was to examine this relationship.

Methods—This study used a cross-sectional, multilevel design with neighborhoods as the primary sampling unit (PSU). Residents (N=1221; aged 50–75) were recruited from 120 neighborhoods in Portland OR. The independent variables at the PSU level involved GIS-derived measures of land-use mix, distribution of fast-food outlets, street connectivity, access to public transportation, and green and open spaces. Dependent variables included resident-level measures of excess adiposity (BMI ≥25), three walking activities, and physical activity. Data were collected in 2006–2007 and analyzed in 2007.

Results—Each unit (i.e., 10%) increase in land-use mix was associated with a 25% reduction in the prevalence of overweight/obesity. However, a 1-SD increase in the density of fast-food outlets was associated with a 7% increase in overweight/obesity. Higher mixed-use land was positively associated with all three types of walking activities and the meeting of physical activity recommendations. Neighborhoods with high street connectivity, high density of public transit stations, and green and open spaces were related in varying degrees to walking and the meeting of physical activity recommendations. The analyses adjusted for neighborhood- and resident-level sociodemographic characteristics.

Conclusions—Findings suggest the need for public health and city planning officials to address modifiable neighborhood-level, built-environment characteristics to create more livable residential communities aimed at both addressing factors that may influence unhealthy eating and promoting active, healthy lifestyles in this rapidly growing population.

Introduction

The incidence and prevalence of overweight and obesity have reached epidemic proportions in the U.S.,[1,2] and they pose a serious threat to public health.[3] Although physical activity is

Address correspondence and reprint requests to: Fuzhong Li, PhD, Oregon Research Institute, 1715 Franklin Blvd., Eugene OR 97403. E-mail: fuzhongl@ori.org.

No financial disclosures were reported by the authors of this paper.

NIH-PA Author Manuscript
NIH-PA Author Manuscript

NIH-PA Author Manuscript

NIH-PA Author Manuscript

known to be important in preventing or decreasing weight gain, research indicates that the majority of U.S. adults are either insufficiently active or sedentary.[4–8] It is well documented that obesity, physical inactivity, or the combination is associated with an increased risk of common chronic diseases, including coronary heart disease, stroke, some cancers, and type 2 diabetes.[9] While obesity and physical inactivity result from the interaction of genetic, behavioral, and environmental factors, there is growing research interest in how these problems are associated with the built environment.[10–18] In this respect, accumulating evidence—primarily from cross-sectional studies—has shown how social, physical, and built-environment conditions may adversely affect health by facilitating unhealthy eating and compromising physical activity.[19–30]

Despite the increase in research on obesity and physical inactivity, there is a paucity of information on built-environment factors and their associations with health and physical activity in a population inclusive of the immediate pre-Baby Boom/early-Baby Boom generations, which will become the major demographic related to healthcare utilization in the next 20 years. According to the U.S. Census Bureau,[31] by 2030 people aged ≥50 will constitute 36% of the total U.S. population (compared to 24.9% currently), and the numbers of those aged ≥60 will more than double from current levels (ranging from an 82% increase in people aged 60–64 to a 126% increase in those aged ≥85). The continuing increase in the number of older adults who are overweight or obese[32] or who do not regularly engage in physical activity[4] makes critical an understanding of how neighborhood built-environments may affect health and physical activity in this population.

This study examined, via a cross-sectional design, the associations among built-environment factors (representing dimensions of urban form), the prevalence of overweight/obesity, and various forms of physical activity among middle-aged and older adults. It was postulated that the neighborhood built-environment factors specified in this study would independently account for neighborhood-level variation in residents' levels of being overweight/obese and physically active. On the basis of prior research,[19,20,22,25–27,29,33] the specific hypotheses were that neighborhoods with lower mixed-land use and higher densities of fast-food outlets would be associated with more residents being overweight/obese, and that residents living in neighborhoods with higher mixed-land use, high street connectivity, better access to public transportation, and more green and open spaces for recreation would be more likely to engage in neighborhood and utilitarian-related walking, as well as to meet the recommended guidelines for physical activity.

Methods

The Study's Geographic Area

The study's geographic area covered the Portland OR metropolitan region's urban growth boundary (UGB). The UGB, created as part of the statewide land-use planning program, is a legal boundary to protect farms and forests from urban sprawl and to promote the efficient use of land, public facilities, and services inside the boundary. The 2005 UGB contained 798 census block groups (a subdivision of U.S. census tracts), encompassing approximately 400 square miles (about 256,345 acres) across the three counties of Washington, Multnomah, and Clackamas. Per the U.S. 2000 census, approximately 1.3 million people lived within the UGB, with a population density of 5956 per square mile. Adults aged ≥50 accounted for approximately 25% of the population.

Study Design and Sampling

A three-stage, stratified sampling strategy was employed. The sampling began by selecting all census block groups (N=798)—used as proxies for neighborhoods—within the UGB. These neighborhoods were the primary sampling unit (PSU) from which the resident sample was drawn. In drawing the sample at Stage 1, the PSUs were stratified according to land-use mix, SES, and ethnic mix. After removing nine unsuitable census block groups (e.g., airports, forest parks, industry, and wildlife sanctuary areas), the remaining 789 block groups were cross-classified on three geographic- and census-derived stratification indicators: (1) land-use mix,[34] (2) SES, and (3) race. This classification scheme produced eight strata; 15 block groups were randomly drawn from each stratum, resulting in a stratified probability sample of 120 block groups (neighborhoods). In Stage 2, households within these neighborhoods were randomly sampled. In Stage 3, sampling was conducted for one eligible study participant within each selected household.

The target adult population consisted of English-speaking adults aged 50–75 who were independently ambulatory (including cane use) and cognitively intact.[35] The target sample size at the resident level was 1200 across the 120 PSUs. Proportional allocation was used to determine the size of the resident sample in each neighborhood, with numbers varying from 5–8 residents for small population block groups to 9–21 residents for medium-to-large population block groups.

Procedures

Selected household residents were initially sent an invitation to participate, which provided some study details and advised the recipient that an interviewer would telephone within a week to arrange a suitable time to conduct the face-to-face survey interview. At this initial telephone contact, the participant’s age was confirmed, and an appointment was scheduled for the personal interview, which took place either at the resident’s home or a research office. To reach selected residents, up to eight call-backs were made before the attempt was considered a nonresponse (i.e., not home). All measures were taken by research interviewers in 2006–2007. The research protocol was approved by the IRB of the Oregon Research Institute.

Measures

Dependent Measures

Objective anthropometric measures of body weight (in pounds) and height (in inches) were obtained from the study participants. BMI was calculated and assigned to two categories: 1=overweight or obese (BMI ≥25); 0=otherwise (BMI <25). Physical activity measures were: (1) neighborhood walking; (2) walking for transportation (e.g., to catch a bus, light rail, or train); (3) walking for household errands (e.g., shopping or banking); and (4) measures of physical activity derived from the Behavioral Risk Factor Surveillance System (BRFSS) survey.[36] All physical activity measures were assessed for frequency and duration (in minutes). These values were multiplied to provide the total number of minutes of each activity in a usual week (7 days). On the basis of these calculations, the study variables were operationally defined as follows: neighborhood (recreational) walking: reporting ≥150 minutes neighborhood walking in a usual week=1, otherwise=0; and walking for transportation and household errands: ≥30 minutes in a usual week=1, otherwise=0. The BRFSS physical activity measures assessed the number of days per week and the total time per day spent in moderate and vigorous physical activity. Physical activity levels were computed into three categories per the established recommendations for physical activity for older adults[7,37,38]: (1) met guidelines for moderate physical activity (≥5 times per week, ≥30 minutes per day) or vigorous physical activity (≥3 times per week, ≥20 minutes per day); (2) insufficiently active (some physical activity but less than the guidelines recommend); or (3) inactive (no physical activity reported). For this study, the latter two categories were combined to create a dichotomous variable of *meets recommendation*=1 or *does not meet recommendation*=0.

Environment Data Sources and Variable Construction

The existing geographic databases provided by the Regional Land Information System (RLIS; www.metro-region.org) were utilized. RLIS maintains a current street address database as well as many other data layers (e.g., tax assessor's data, regional land-use data from digital aerial photography, employment data, census data) from which the characteristics of urban form as well as neighborhood demographic and built-environment features relevant to this study were derived. Information on the types of fast-food restaurants was obtained via a commercially purchased business dataset (http://infousa.com) and subsequently compiled, using proprietary 4-digit extensions to the Standard Industrial Classification codes. Included were various fast-food chain restaurants such as McDonald's, Subway, Burger King, and Wendy's. All these data were spatially integrated within a GIS, using ArcView software to characterize the built environment of the sampled study area.

Five built-environment variables were constructed: land-use mix, density of fast-food outlets, density of street connectivity, density of public transit stations, and area of green and open spaces for recreation. Brief operational definitions for each appear below.

Land-use mix—Land-use mix was operationalized using the method provided by Frank et al.,[23] which provides a measure of the evenness of distribution of several land-use types (i.e., residential, public [offices and institutions], and commercial land uses) within the study's geographic area. Values near 0 reflect single-use environments such as residential suburbs, while values near 1 reflect maximal mixed usage.

Density of fast-food outlets—The number of fast-food outlets divided by area in square miles.

Density of street connectivity—The number of street intersections, including those with traffic lights and those without, divided by area in square miles.

Density of public transit stations—The number of bus and transit stations divided by area in square miles.

Green and open spaces—The total acreage of green and open spaces for recreation, including public parks and playgrounds.

All environmental variables, with the exception of land-use mix, were standardized to enhance the interpretation of results. In addition, four measures were developed, using 2000 Census data to represent neighborhood-level socioeconomic characteristics: (1) median household income, (2) percentage of African-American residents, (3) percentage of Hispanic residents, and (4) residential density (defined as the number of people per residential acre). These measures were used as study covariates.

Participant-Level Measures

Data obtained from individual participants included age, gender, education, race/ethnicity, employment status, household income, home ownership, alcohol use, tobacco use, general health status, BMI, fruit and vegetable intake,[39] and fried-food consumption (which was assessed via a single item: *How many servings of fried food [e.g., deep-fried in oil, pan-fried in oil or butter, etc.] do you have per day in a typical week?*).

Data Analysis

By design, the data in this study are hierarchically structured (i.e., residents are nested within neighborhoods), thus making it appropriate for a multilevel analysis that allows for the

NIH-PA Author Manuscript

NIH-PA Author Manuscript

simultaneous estimation of associations among neighborhood-level and resident-level factors and response outcomes. Within the hierarchical generalized linear modeling framework,[40,41] a series of multilevel Poisson regression models were fitted, using a logarithmic link with Poisson variation represented by between-neighborhood random effects.[41] Poisson regression was chosen over logistic regression to avoid over-estimation problems in the estimated OR, as occurs when the prevalence of the outcome is >10%.[42,43]

Five multilevel models were specified and estimated (one for each of the five dependent variables: overweight/obesity, three walking activities, meeting recommended levels of physical activity). For the model of overweight/obesity, neighborhood-level measures included the primary independent variables of land-use mix, fast-food density, and covariates. For the models of walking and meeting recommended physical activity, neighborhood-level measures included the primary independent variables of land-use mix, street-connectivity density, public transit-station density, green and open spaces for recreation, and covariates. In all models, neighborhood-level covariates included residential density, median household income, and percentage of African-American and Hispanic residents. Based on prior studies,[19–23] resident-level covariates included age, gender, race/ethnicity, employment status, home ownership, household income, health status, fruit and vegetable intake, and fried-food consumption. BMI, used as a resident-level covariate, was included in the four physical activity models.

For each outcome analysis, estimation involved fitting a sequence of nested models: (1) a two-level random intercept model (i.e., without covariates/predictors at either level); (2) a model with individual-level covariates; (3) a model with neighborhood-level covariates; and (4) a model including all Level-1 and -2 covariates as well as Level-2 built-environment variables. Parameter estimates (log coefficients [e.g., overweight/obesity prevalence]); exponentiated coefficients (exp [log coefficients]); and their 95% CIs from each model are presented. The coefficients are interpreted as the expected prevalence (i.e., exp [log coefficient]) of the dependent variable for a unit change in land-use mix or a 1-SD change in fast-food outlets, street connectivity, public transit stations, or green and open spaces, holding constant the other covariates/predictors in the model.

Results

Sample Characteristics

Valid responses were obtained from 1221 respondents (a 48% response rate from all selected participants initially contacted). All participants' addresses were successfully geo-matched for an accuracy level of 100%. The map showing the geocoded home locations of participants across the 120 study neighborhoods is displayed in Figure 1.

Table 1 shows the descriptive statistics for the study sample and by gender. Respondents were aged 50–75 (mean age=62 years, SD=6.89 years). The majority of respondents were men (57%); married (64%); white (92%); and lived in a house (80%). Most had some college or higher (77%) and a household income of $50,000 or higher (53%). More than half of the respondents reported nonfrequent alcohol use (53%); not currently smoking (89%); and perceived their health to be very good or excellent (55%).

More than two thirds of the sample (75%) were overweight or obese, with an average waist circumference of 39.08 inches. Of the total sample, 32% of the respondents reported at least 150 minutes of neighborhood walking weekly; 12% reported 30 minutes of weekly walking for transport, whereas approximately 38% reported 30 minutes of weekly walking for household errands. Approximately 64% of the respondents reported meeting either moderate or vigorous physical activity recommendations.

Multilevel Analyses

Table 2 shows the random effects estimated from the multilevel Poisson regression models for each of the five outcomes. Estimates of the intraclass correlations show a noticeable amount of variation between neighborhoods, providing sufficient justification for examining between-neighborhood variation on the outcome variables with the multilevel analysis. Also, all random coefficients were significant when no predictors (i.e., an unconditional model) were included (Model 0). Significant reductions in variation among neighborhoods were observed when moving from the unconditional model (Model 0) to the substantive model (Model 3; see Columns 3–6). Finally, the model for each variable explained small-to-significant amounts of variance at the neighborhood level after addition of the key built-environment variables (last column), with the proportion of neighborhood-level variance accounted for ranging from 0.23 (meeting activity recommendations) to 0.98 (overweight/obese).

Major outcomes of the multilevel Poisson regression model analyses are summarized in Table 3. Land-use mix and fast-food density were significantly associated with the likelihood of residents being overweight/obesity (p's<0.01). Specifically, a 1-unit (i.e., 10%) increase in the even distribution of square footage across all four land uses (i.e., residential, public [offices and institutions], commercial) was associated with a 25% reduction in the prevalence of overweight/obesity, holding other variables in the model constant. However, a 1-SD increase in the density of fast-food outlets was associated with a 7% increase in the prevalence of overweight/obesity, holding constant other variables in the model.

Significant associations were also observed between the built-environment factors and the dependent variables that represented various forms of physical activity. Specifically, higher mixed-use land was consistently shown to be positively associated (p's<0.05) with all three types of neighborhood-based walking activities and meeting physical activity recommendations ($p<0.03$). For example, a 1-unit increase in mixed-land use was associated with a 5.76-times increase in walking for transportation (Table 3, Column 5). Similarly, neighborhoods with high street connectivity were shown to be significantly related to a higher prevalence of walking (p's≤0.03) and meeting physical activity recommendations ($p<0.001$). For example, a 1-SD increase in street connectivity increased walking prevalence by 16% for neighborhood walking, 20% for transportation, and 11% for errands, respectively. Finally, the density of public transit stations was associated with more walking for transportation ($p<0.01$) and meeting physical activity recommendations ($p=0.03$); green and open spaces for recreation were also associated with more neighborhood walking ($p=0.03$) and meeting physical activity recommendations ($p<0.001$).

With respect to model covariates at the neighborhood level, a 1% increase in the African-American population reduced the likelihood of neighborhood walking by 5%. In contrast, a 1% increase in the Hispanic population in neighborhoods was associated with an approximately 1% increase in meeting recommended physical activity. At the resident level, there was a higher prevalence of overweight/obesity in women than men, and residents with less education were associated with a higher prevalence of overweight/obesity but were more likely to walk for errands. Residents with better health status were less likely to be overweight/obese. In all four physical activity outcomes, residents with lower BMI were associated with a greater likelihood of walking and meeting physical activity recommendations.

Discussion

The results from this study showed significant associations among built-environment factors and the prevalence of overweight/obesity and various forms of physical activity in middle-aged and older adults. Controlling for neighborhood- and resident-level sociodemographic characteristics, neighborhoods with lower mixed-land use and higher densities of fast-food outlets were more likely to have residents who were overweight/obese. In contrast, residents living in neighborhoods with higher mixed-land use, high street connectivity, better access to public transit stations, and more green and open spaces for recreation were more likely to engage in some form of neighborhood-based walking, and, more importantly, to meet physical activity recommendations.

Although an association between the built environment and physical activity is demonstrated, it is clear that built-environment factors were differentially associated with each type of walking activity. For example, mixed-land use, high street connectivity, and more green and open spaces were important for residents when engaging in neighborhood walking, but public transit station distribution was not. Highly connected neighborhood streets and access to public transit stations were associated with a higher prevalence of walking for transportation, whereas only street connectivity was significantly associated with walking for household errands. Above all, neighborhoods with more mixed-land use had a higher prevalence of all three types of neighborhood-based walking.

Findings from this study are consistent with those of previous studies of general adult populations that involved common urban-form measures. For example, better mixed-land use has been associated with a reduction in the likelihood of obesity in adult populations.[20,22] Other urban forms such as street connectivity, along with open and green space, have been shown to be conducive to increased levels of physical activity, including walking.[19,20,23,25] This study, however, extends previous work by using multilevel design and analyses to estimate, within a single framework, an association among mixed-land use and the density of fast-food outlets at the neighborhood level and levels of overweight/obesity and physical activity in a sample of urban middle-aged and older residents. The focus on the Baby-Boom generation is an important extension of existing studies by demonstrating associations between built-environment features and health-related characteristics in an aging population that, because of its magnitude, is going to have a profound influence on healthcare allocation and utilization in the coming decades. Understanding—and modifying—the factors associated with good health can lessen the economic and social burden of chronic, lifestyle-related disabilities, as well as enhance individual quality of life.

Results from this study underscore the importance of built-environment influences on overweight/obesity and physical activity. Important implications from this study are that fast-food outlets across neighborhoods are negatively associated with residents' health outcomes, in that a greater distribution of fast-food restaurants is associated with a greater prevalence of overweight/obesity among neighborhood residents. However, the prevalence of overweight/obesity may be lower in neighborhoods that have higher levels of mixed-land use (i.e., a mix of commercial, residential, and public land). Similarly, public health strategies to promote physical activity or walking should emphasize the important role of environmental influences that facilitate opportunities for people to be more active. In this respect, findings from the current study suggest that high street connectivity, better access to public transit stations, and more green and open spaces for recreation are likely to increase urban mobility and favor the establishment of walkable neighborhoods. These results collectively suggest that city planning, zoning policies, and community health promotion should consider built environments that facilitate residents' health and physical activity.

Study Strengths and Limitations

This study has several strengths. First, it studied a demographic that will have a significant impact on healthcare resources in the coming decades. Second, health and physical activity are related to objectively measured built-environment variables at the relatively small geographic scale of local neighborhoods. Third, the sampling frame chosen can be considered "… a sort of living laboratory of efficient urban planning and living,"[44] with a range of low-to-high commercial and residential densities, mixed-land use, and interconnected streets that support walking for utilitarian purposes, transportation, and physical activity. These features provided a natural setting for studying urban growth-management policies and the built environment's impact on health outcomes.[45] Another notable strength is the focus on the distribution of fast-food restaurants and land-use mix, two features of the built environment that are relevant to overweight/obesity and physical activity. This information, coupled with varied measures of walking (i.e., leisure-time, transportation, errands) and general physical activity, has direct policy applicability, indicating how major features of the built environment are related to the problem of overweight/obesity and the specific forms of physical activity in local communities.

This study also has limitations. First, the use of a cross-sectional design limits the identification of a causal link between the built-environment variables and health and physical activity. In this regard, the results provided a snapshot of an ongoing dynamic process. Second, the study sample was relatively homogenous, economically stable, and health-conscious. Future studies need to replicate this work in other urban populations. Third, the design does not account for the potential effects of self-selection or attitudinal pre-determinants of community living choice, or the choice to walk for various purposes.[23] While the presence of fast-food outlets in a neighborhood is associated with a higher risk of overweight/obesity, it is plausible that the decision of fast-food franchises to operate their businesses in particular locations occurs in response to the tastes or needs of local residents. In these cases, residents' lifestyle choices and/or tastes/demands may be related both to the location of outlets and to the risk of overweight/obesity. Finally, because of the primary research focus on the neighborhood level, the current study did not examine how the built environment (land-use patterns) near each resident's home is associated with health and physical activity. Future study should focus on the block-level environment of residents.

Conclusion

The current study contributes to the environment and health literature by documenting associations among built-environment factors, particularly those related to urban form, and overweight/obesity and physical activity in a sample of middle-aged and older adults. On the basis of the cross-sectional analysis results, findings indicate that lower mixed-land use and higher densities of fast-food outlets in a neighborhood are associated with a higher prevalence of overweight/obesity in local residents, whereas a high-density land-use mix is associated with a higher prevalence of physical activity. These findings collectively suggest that public health and city planning professionals need to consider how modifiable neighborhood-level, built-environment characteristics can create more livable residential communities and promote active, healthy lifestyles.

Acknowledgements

The work presented in this paper is supported by a research grant from the National Institute of Environmental Health Sciences, NIH (Grant #1R01ES014252).

References

1. CDC. U.S. obesity trends: 1985–2006. www.cdc.gov/nccdphp/dnpa/obesity/trend/maps/index.htm
2. Flegal KM, Carroll MD, Ogedn CL, et al. Prevalence and trends in obesity among U.S. adults, 1999–2000. JAMA 2002;288:1723–7. [PubMed: 12365955]
3. USDHHS. The Surgeon General's call to action to prevent and decrease overweight and obesity. Rockville MD: U.S. Public Health Services, Office of the Surgeon General; 2001.
4. Brown DR, Yore MM, Ham SA, Macera CA. Physical activity among adults ≥50 yr with and without disabilities, BRFSS 2001. Med Sci Sports Exerc 2005;37:620–9. [PubMed: 15809561]

5. CDC. Prevalence of physical activity, including lifestyle activities among adults—U.S. 2000–2001. MMWR Morb Mortal Wkly Rep 2003;52(32):764–9. [PubMed: 12917582]

6. CDC. Prevalence of no leisure-time physical activity–35 States and the District of Columbia, 1988–2002. MMWR Morb Mortal Wkly Rep 2004;53(4):82–6. [PubMed: 14762333]

7. Haskell WL, Lee IM, Pate RR, et al. Physical activity and public health: updated recommendation for adults from American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39(8):1423–34. [PubMed: 17762377]

8. USDHHS. Healthy People 2010. 2www.healthypeople.gov/publications/

9. USDHHS. Physical activity and health: a report of the Surgeon General. Atlanta GA: USDHHS, CDC, National Center for Chronic Disease Prevention and Health Promotion; 1996.

10. Dannenburg A, Jackson RJ, Frumkin H, et al. The impact of community design and land-use choices on public health: a scientific research agenda. Am J Public Health 2003;93:1500–8. [PubMed: 12948970]

11. Ewing R. Can the physical environment determine physical activity levels? Exerc Sport Sci Rev 2005;33(2):69–75. [PubMed: 15821427]

12. Ewing R, Cervero R. Travel and the built environment: a synthesis. Transportation Res Record 2001;1780:87–114.

13. Frank, LD.; Engelke, PO.; Schmid, TL. Health and community design: the impact of the built environment on physical activity. Washington DC: Island Press; 2003.

14. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. Am J Prev Med 2002;22:188–99. [PubMed: 11897464]

15. Lavizzo-Mourey R, McGinnis JM. Making the case for active living communities. Am J Public Health 2003;93:1386–8. [PubMed: 12948948]

16. Li F, Fisher KJ, Bauman A, et al. Neighborhood influences on physical activity in older adults: a multilevel perspective. J Aging Phys Activ 2005;13:87–114.

17. Saelens BE, Sallis JF, Frank LE. Environmental factors that promote walking and cycling: findings from the transportation, urban design and planning literatures. Ann Behav Med 2003;25:80–91. [PubMed: 12704009]

18. Sallis, JF.; Owen, N. Ecological models. In: Glanz, K.; Lewis, FM.; Rimer, BK., editors. Health behavior and health education: theory, research and practice. 3. San Francisco CA: Jossey-Bass; 2002.

19. Berke EM, Koepsell TD, Moudon AV, Hoskins RE, Larson EB. Association of the built environment with physical activity and obesity in older persons. Am J Public Health 2007;97:486–92. [PubMed: 17267713]

20. Ewing R, Schmid T, Killingsworth R, Zlot A, Raudenbush S. Relationship between urban sprawl and physical activity, obesity, and morbidity. Am J Health Promot 2003;18:47–57. [PubMed: 13677962]

21. Fisher JK, Li F, Michael Y, Cleveland M. Neighborhood level influences on physical activity among older adults: a multilevel analysis. J Aging Phys Activ 2004;11:49–67.

22. Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. Am J Prev Med 2004;27:87–96. [PubMed: 15261894]

23. Frank LD, Schmid TL, Sallis JF, Chapman J, Saelens BE. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. Am J Prev Med 2005;28 (2S):117–25. [PubMed: 15694519]

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 U.S. middle-aged and older-aged women. Health Psychol 2000;19:354–64. [PubMed: 10907654]

25. Li F, Fisher KJ, Brownson BC, Bosworth M. Multilevel modeling of built environmental characteristics in relation to neighborhood walking activity in older adults. J Epidemiol Community Health 2005;59:558–64. [PubMed: 15965138]

26. Maddock J. The relationship between obesity and the prevalence of fast food restaurants: State-level analysis. Am J Health Promot 2004;19:137–43. [PubMed: 15559714]

27. Morland K, Diez Roux AV, Wing S. Supermarkets, other food stores, and obesity: the atherosclerosis risk in communities study. Am J Prev Med 2006;30:333–9. [PubMed: 16530621]

28. Powell LM, Chaloupka FJ, Bao Y. The availability of fast-food and full-service restaurants in the U.S. : associations with neighborhood characteristics. Am J Prev Med 2007;33(4S):S240–S245. [PubMed: 17884571]
29. Rundle A, Roux Diez AV, Freeman LM, Miller D, Neckerman KM, Weiss CC. The urban built environment and obesity in New York City: a multilevel analysis. Am J Health Promot 2007;21(4): 326–34. [PubMed: 17465178]
30. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. Am J Public Health 2003;93:1552–8. [PubMed: 12948979]
31. U.S. Census Bureau. Population pyramids of U.S. Population division, interim state population projections. www.census.gov/population/www/projections/regdivpyramid.html
32. Arterburn DE, Crane PK, Sullivan SD. The coming epidemic of obesity in elderly Americans. J Am Geriatr Soc 2004;52:1907–12. [PubMed: 15507070]
33. Mehta NK, Chang VW. Weight status and restaurant availability: a multilevel analysis. Am J Prev Med 2008;34(2):127–33. [PubMed: 18201642]
34. Song Y, Knapp GJ. Measuring urban form: Is Portland winning the war on sprawl? J Am Planning Asso 2004;70:210–25.
35. Pfeiffer E. Short portable mental status questionnaire. J Am Geriatr Soc 1975;23:433–41. [PubMed: 1159263]
36. CDC. Behavioral Risk Factor Surveillance System. www.cdc.gov/brfss
37. Nelson ME, Rejeski WJ, Blair SN, et al. Physical activity and public health in older adults: recommendation from the American College of Sports Medicine and the American Heart Association. Med Sci Sports Exerc 2007;39:1435–45. [PubMed: 17762378]
38. 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;273:402–7. [PubMed: 7823386]
39. Thompson FE, Kipnis V, Subar AF, et al. Evaluation of 2 brief instruments and a food-frequency questionnaire to estimate daily number of servings of fruit and vegetables. Am J Clin Nutr 2000;71 (6):1503–10. [PubMed: 10837291]
40. Raudenbush, SW.; Bryk, AS. Hierarchical linear models. Thousands Oaks CA: Sage Publications; 2002.
41. Raudenbush, SW.; Bryk, A.; Cheong, YF.; Congdon, R. HLM6: Hierarchical linear and nonlinear modeling. Lincolnwood IL: Scientific Software International; 2004.
42. McNutt LA, Wu C, Xue X, Hafner JP. Estimating the relative risk in cohort studies and clinical trials of common outcomes. Am J Epidemiol 2003;157:940–3. [PubMed: 12746247]
43. Zou G. A modified Poisson regression approach to prospective studies with binary data. Am J Epidemiol 2004;159:702–6. [PubMed: 15033648]
44. Benfield, FK.; Raimi, MD.; Chen, DD. Once there were green fields: how urban sprawl is undermining America’s environment, economy and social fabric. New York: Natural Resources Defense Council; 1999.
45. Abbott, C. Planning a sustainable city: the promise and performance of Portland’s urban growth boundary. In: Squires, GD., editor. Urban sprawl: causes, consequences and policy responses. Washington DC: Urban Institute Press; 2002.

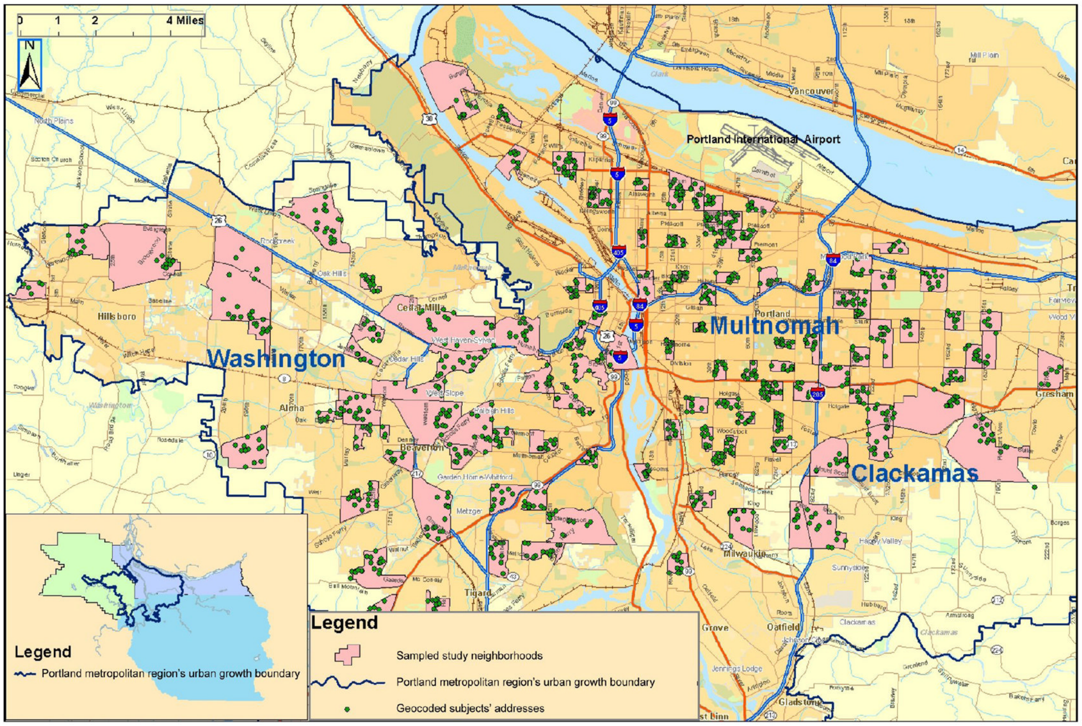

Figure 1.
Map of geocoded residences of participants across 120 study neighborhoods within the Portland, Oregon, metropolitan region’s urban growth boundary

Table 1

Demographic characteristics of the resident-level sample population and by gender

Demographic	M (range, SD) or number (%)		
	Men (*n*=698)	Women (*n*=523)	Total (N=1221)[a]
Age (mean, range)	62 (50–75)	62 (50–75)	62 (50–75)
Race/ethnicity			
White	648 (92.9)	477 (91.2)	1125 (92.1)
Black	15 (2.1)	21 (4.0)	36 (2.9)
Asian	15 (2.1)	10 (1.9)	25 (2.0)
Other ethnicity	20 (2.9)	15 (2.9)	35 (3.0)
Marital status			
Married	577 (82.7)	198 (37.9)	775 (63.5)*
Single	121 (17.3)	325 (62.1)	446 (36.5)*
Employment status			
Retired	289 (41.4)	238 (45.5)	527 (43.2)
Working (either part time or full time)	385 (55.2)	248 (47.4)	633 (51.8)
Unemployed	24 (3.4)	37 (7.1)	61 (5)
Education			
Less than high school	5 (0.7)	0	5 (0.4)
High school graduate	131 (18.8)	144 (27.5)	275 (22.5)
Some college or higher	562 (80.5)	379 (72.5)	941 (77.1)
Household income ($)			
≤14,999	13 (1.9)	51 (9.8)	64 (5.2)
15,000–24,999	71 (10.2)	89 (17)	160 (13)
25,000–49,999	170 (24.4)	175 (33.5)	345 (28.3)
≥50,000	444 (63.5)	208 (39.7)	652 (53.5)*
Living situation			
Detached single house	606 (86.9)	376 (71.9)	982 (80.4)*
Duplex	8 (1.1)	16 (3.1)	24 (2.2)
Townhouse	8 (1.1)	22 (4.2)	30 (2.5)
Apartment	61 (8.8)	89 (17)	150 (12.2)
Mobile home or trailer	7 (1.0)	16 (3.1)	23 (1.8)
Other	8 (1.1)	4 (0.7)	12 (0.9)
Property owner			
Homeowner	633 (90.7)	444 (84.9)	1077 (88.2)*
Rented	60 (8.6)	76 (14.5)	136 (11.1)
Other	5 (0.7)	3 (0.6)	8 (0.7)
Drink alcohol/week			
<1	315 (45.1)	337 (64.4)	652 (53.4)*
1–4	212 (30.4)	121 (23.2)	333 (27.3)
≥5	171 (24.5)	65 (12.4)	236 (19.3)*
Tobacco use			
Never smoked/chewed	321 (46)	266 (50.9)	587 (48.1)
Ex-smoker/chewer	300 (43)	197 (37.6)	497 (40.7)
Current smoker/chewer	77 (11)	60 (11.5)	137 (11.2)
Health status			
Excellent	140 (20.1)	96 (18.4)	236 (19.3)
Very good	257 (36.8)	181 (34.6)	438 (35.9)*
Good	206 (29.5)	142 (27.2)	348 (28.5)
Fair	71 (10.2)	84 (16.0)	155 (12.7)
Poor/very poor	24 (3.4)	20 (3.8)	44 (3.6)
Common medical conditions (mean, SD)[b]	1.843 (0.15)	1.806 (0.16)	1.825 (0.15)*
BMI (kg/m^2)			
Normal (18.5–24.9)	137 (19.6)	172 (32.9)	309 (25.3)*
Overweight (25.5–29.9)	302 (43.3)	152 (29.1)	454 (37.2)*
Obese (30 and above)	259 (37.1)	199 (38)	458 (37.5)
Waist-to-hip ratio (mean, SD)	0.959 (0.08)	0.841 (0.07)	0.900 (0.10)*
Meeting physical activity recommendations			
Moderate activity			
No moderate activity	95 (13.6)	61 (11.7)	156 (12.8)
Insufficient moderate activity	116 (16.6)	91 (17.4)	207 (17)
Meets guidelines	487 (69.8)	371 (70.9)	858 (70.2)
Vigorous activity			
No vigorous activity	287 (41.1)	269 (51.4)	556 (45.5)*
Insufficient vigorous activity	136 (19.5)	102 (19.5)	238 (19.5)
Meets guidelines	275 (39.4)	152 (29.1)	427 (35)*
Systolic blood pressure (mm Hg)	138.2 (16.99)	130.97 (17.54)	134.59 (17.59)*
Diastolic blood pressure (mm Hg)	83.54 (10.91)	79.06 (10.75)	81.30 (11.06)*

[a]Indicates a test performed using either independent t-test for gender differences in means or a test in differences in proportions, $p<0.05$ (2-tailed).

[b]This is measured out of nine possible common medical conditions (e.g., diabetes, hypertension, depression).

*$p<0.05$

NIH-PA Author Manuscript

NIH-PA Author Manuscript

Table 2

Neighborhood-level random components from multilevel Poisson regression models

Outcome	Neighborhood-level random coefficient[a]					Proportion of neighborhood-level variance explained[d]
	ICC[b]	Model 0[c]	Model 1[c]	Model 2[c]	Model 3[c]	
Overweight/obese	0.11	0.007*	0.001	0.00054	0.00001	0.981
Neighborhood walking	0.41	0.365**	0.295**	0.294**	0.126**	0.571
Walking for transportation	0.55	0.564**	0.467**	0.465**	0.291**	0.374
Walking for errands	0.38	0.185**	0.137**	0.101**	0.071**	0.297
Meeting physical activity recommendations	0.40	0.089**	0.097**	0.090**	0.069**	0.233

[a]Random coefficient (variance) at the neighborhood level-variance in Model 0 represents random variation in neighborhoods whereas variance in Model 1 through Model 3 denote residual variance conditional on model covariates/predictors.

[b]Intraclass correlations (ICC) is defined as a ratio of between-neighborhood variability/(between-neighborhood variability + within-neighborhood variability).

[c]Model 0: unconditional model (i.e., no level-specific predictors/covariates); Model 1: model with only individual-level covariates; Model 2: model with both individual- and neighborhood-level covariates; Model 3: model with both individual- and neighborhood-level covariates and key built-environment predictors.

[d]This is the proportion of variance explained at neighborhood level after addition of the neighborhood-level key built-environment variables, calculated as: {variance (Model 2)–variance (Model 3)/ variance (Model 2), where variance (Model 2) represents the total between-neighborhood-level variance that can be explained by addition of the between-neighborhood variables.

*$p<0.05$;

**$p<0.001$

Table 3

Adjusted estimates of neighborhood-level Poisson regression model analyses: associations between built-environment factors, overweight/obese, and various forms of physical activity[a]

Model variables	Coefficient	SE	*p*-value	Estimated prevalence[b]	95% CI
Overweight/obese					
Land-use mix	−0.289	0.092	0.003	0.749	0.624, 0.899
Fast food outlets	0.067	0.018	0.001	1.069	1.031, 1.108
Neighborhood walking					
Land-use mix	1.403	0.291	<0.000	4.066	2.285, 7.234
Street connectivity	0.148	0.068	0.034	1.159	1.012, 1.328
Public transit stations	0.061	0.057	0.291	1.062	0.949, 1.191
Green and open spaces	0.111	0.051	0.032	1.119	1.010, 1.238
Percentage African-American	−0.047	0.013	0.001	0.954	0.930, 0.979
Walking for transportation					
Land-use mix	1.752	0.384	<0.001	5.764	2.698, 12.314
Street connectivity	0.180	0.061	0.004	1.198	1.062, 1.351
Public transit stations	0.137	0.053	0.011	1.147	1.033, 1.272
Green and open spaces	0.079	0.061	0.192	1.083	0.960, 1.221
Walking for errands					
Land-use mix	0.402	0.201	0.047	1.495	1.005, 2.223
Street connectivity	0.104	0.046	0.025	1.109	1.014, 1.214
Public transit stations	0.037	0.034	0.274	1.038	0.970, 1.111
Green and open spaces	0.037	0.023	0.116	1.038	0.991, 1.089
Meeting physical activity recommendations					
Land-use mix	0.380	0.167	0.025	1.463	1.050, 2.039
Street connectivity	0.162	0.035	<0.001	1.176	1.096, 1.262
Public transit stations	0.068	0.031	0.03	1.069	1.007, 1.137
Green and open spaces	0.062	0.015	<0.001	1.065	1.031, 1.098
Percentage Hispanic	0.007	0.003	0.032	1.007	1.001, 1.014

[a]Adjusting for neighborhood-level covariates of residential density, median household income, percentage of African-American and Hispanic residents, and resident-level covariates of age, gender, race/ethnicity, employment status, home ownership, household income, health status, fruit and vegetable intake, fried-food consumption, and BMI.

[b]Prevalence=exp (coefficient).