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Relationships Between the Built Environment and Walking and Weight Status Among Older Women in Three U.S. States

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Abstract

There are few studies of built environment associations with physical activity and weight status among older women in large geographic areas that use individual residential buffers to define environmental exposures. Among 23,434 women (70.0±6.9 years; range = 57-85) in 3 states, relationships between objective built environment variables and meeting physical activity recommendations via walking and weight status were examined. Differences in associations by population density and state were explored in stratified models. Population density (odds ratio (OR)=1.04 [1.02,1.07]), intersection density (ORs=1.18-1.28), and facility density (ORs=1.01-1.53) were positively associated with walking. Density of physical activity facilities was inversely associated with overweight/obesity (OR=0.69 [0.49, 0.96]). The strongest associations between facility density variables and both outcomes were found among women from higher population density areas. There was no clear pattern of differences in associations across states. Among older women, relationships between accessible facilities and walking may be most important in more densely populated settings.

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By 2030, 20% of the U.S. population or an estimated 71 million individuals will be 65 years of age or older (Centers for Disease Control and Prevention [CDC], 2003). Physical inactivity and obesity increase the risks of chronic diseases and conditions, such as diabetes and arthritis (Manson et al., 1991; Patterson, Frank, Kristal, & White, 2004) that disproportionately affect this population (CDC, 2006; CDC, 2011). Recent physical activity estimates based on objective monitoring showed that older U.S. adults have the lowest levels of activity among all age groups (Troiano et al., 2008). Also, from 2003 to 2006 the highest prevalence of overweight and obesity in the U.S. was among men, ages 55-64 years (80%) and women, ages 65-74 years (71%) (National Center for Health Statistics, 2009). Furthermore, obesity prevalence increased from 15% to 23% among adults 60-69 years of age and from 11% to 16% among those 70 years of age and older from 1991 to 2000 (Mokdad et al., 2001; Mokdad et al., 1999; Villareal, Apovian, Kushner, & Klein, 2005).

The determinants of obesity and physical activities such as walking are multi-factorial (Grundy, 1998; King, 1995; King et al., 1992). Social ecological models of physical activity promotion among older adults underscore the need to use multilevel strategies, including approaches that target the built or human-made environment (Satariano & McAuley, 2003). A relatively small, but growing body of literature has shown that attributes of the built environment, such as residential density (Rodriguez, Evenson, Diez Roux, & Brines, 2009), proximity of facilities and businesses (King et al., 2005), the number of commercial establishments (Nagel, Carlson, Bosworth, & Michael, 2008) and the mix of residential and commercial land uses, street connectivity, and density of public transit (Li et al., 2008), are positively associated with physical activity in older adults. There is also emerging evidence on relationships between the built environment and weight-related outcomes in this population (Berke, Koepsell, Moudon, Hoskins, & Larson, 2007; Grafova, Freedman, Kumar, & Rogowski, 2008; Li et al., 2009b; Li et al., 2008). For example, among a nationally representative sample of persons 50 years of age and older, investigators found that women living in areas with more connected street networks were less likely to be overweight or obese (Grafova et al., 2008). Findings from other recent studies in King County, Washington (Berke et al., 2007) and Portland, Oregon (Li et al., 2009b; Li et al., 2008) have indicated that neighborhood built environment variables, such as higher land use mix and neighborhood walkability, are inversely associated with overweight and obesity among older adults.

Several studies have shown that associations between certain built environment attributes and physical activity may vary across neighborhoods characterized as urban, suburban or rural and by other indicators of geographic location (Berrigan & Troiano, 2002; Duncan, Mummery, Steele, Caperchione, & Schofield, 2009; Hou et al., 2010; Troped, Tamura, Whitcomb, & Laden, 2011). For example, Duncan and colleagues showed that perceived presence of walking paths was significantly associated with walking among Australian adults living in metropolitan areas, but was not a significant correlate among those residing in non-metropolitan areas (Duncan et al., 2009). To our knowledge, this issue has not been examined among older adults. Further research is needed to determine whether relationships between objective measures of the neighborhood built environment and both walking and weight status among older adults are consistent across neighborhood contexts (e.g., urban vs. suburban). Additionally, a limitation of current research among older adults is reliance on samples from relatively small geographic areas, such as a particular city or county (Berke et al., 2007; Fisher, Li, Michael, & Cleveland, 2004; King et al., 2005; Li, Fisher, Brownson, & Bosworth, 2005; Li et al., 2009b; Li et al., 2008; Nagel et al., 2008). Therefore, it is not known whether associations between the built environment and walking are consistent across larger geographic areas, such as from one state or region to another. To address these limitations in the current literature on older adults, we examined associations between objective household-level measures of the built environment and both walking and overweight/obesity in an existing cohort of older women from California, Massachusetts, and Pennsylvania. We examined these relationships, stratifying by population density and then by state. In this study we hypothesized that population density, intersection density, and facility density measures would be positively associated with walking and generally would have negative relationships with overweight/obesity (except for density of convenience stores and fast food outlets). In addition, it was hypothesized that the relationships between facility density variables and walking and weight status would vary across levels of population density and by state.

Methods

Participants

The Nurses' Health Study (NHS) is a prospective cohort study initiated in 1976 with 121,700 female registered nurses from eleven states (California, Connecticut, Florida, Maryland, Massachusetts, Michigan, New Jersey, New York, Ohio, Pennsylvania and Texas). At enrollment in 1976, participants were 30-55 years of age and 97% were White. NHS participants currently reside in all U.S. states. The cohort has been followed with biennial questionnaires that include items on health and health-related behaviors. For the purpose of this analysis, we restricted the population to those living in California, Massachusetts or Pennsylvania as of the 2004 survey. These are three of the five most populated states in terms of NHS participants and were selected to provide regional diversity. The women in these three states are representative of the whole cohort in terms of total physical activity and BMI. Out of 31,922 NHS participants in these three states, 24,791 (77.7%) completed a version of the 2004 survey with physical activity items. Additionally, the 23,434 NHS participants included in this analysis (94.5%) had a home address geocoded to the street number level; had complete information on physical activity, height and weight, and walking limitations; reported they were able to walk; and did not live in a nursing home. Human subjects committees at the Brigham and Women's Hospital and Purdue University approved study protocols.

Walking Outcome

The walking outcome was based on responses to the 2004 NHS survey. Women reported the average time per week they engaged in different types of physical activities over the past year, including walking for exercise or to work. Participants also reported their usual walking pace (i.e., easy/casual [< 2 mph]; normal/average [2-2.9 mph]; brisk [3-3.9 mph]; very brisk/striding [≥ 4 mph]). Reproducibility and validity of the physical activity items have been confirmed (Wolf et al., 1994). Consistent with prior NHS approaches, a metabolic equivalent task (MET) value was assigned for walking based on pace. Walking MET-minutes per week (MET-min/wk) was calculated by multiplying the average weekly minutes of walking by the MET-value. A dichotomous walking outcome was created by categorizing participants as meeting or not meeting the U.S. Department of Health and Human Services recommendation of 500 MET-min/wk of moderate-intensity physical activity based on walking, roughly equivalent to 150 min/wk of walking (U.S. Department of Health and Human Services, 2008).

Weight Status

Participants reported their height in 1976 and weight in subsequent surveys, including 2004. For 1,397 participants who did not report weight in 2004, missing values were replaced with the average of reported weights from the 2002 and 2006 NHS surveys. Body mass index (BMI) was calculated as weight in kilograms divided by height in meters squared. A binary outcome was created by categorizing participants with BMI ≥18.5 and < 25.0 as normal weight, and BMI ≥ 25.0 as overweight/obese. Underweight (BMI < 18.5) participants (n=473) were excluded from the analyses for which weight status was the outcome.

Built Environment

Three types of built environment variables were created using geographic information systems (GIS): (a) population density, (b) intersection density, and (c) density of facilities. All built environment variables were analyzed within 800 m and 1200 m line-based road network buffers. This buffer extends from the home address along the road network excluding highways and includes 50 m on both sides of the road centerline. Thus, analyses are restricted to areas that are physically accessible to residents from streets (Oliver, Schuurman, & Hall, 2007).

Population density was created using LandScan™ data (Oak Ridge National Laboratory, 2006). This measure represents ambient population (integrating daily movements and collective travel habits), and incorporates road proximity, slope, land cover, and nighttime lights, in addition to census counts. Population density was calculated as the number of persons per square kilometer of area within the buffer. For stratified analyses population density was categorized into percentile ranges: 0-20, 20.1-40, 40.1-60, 60.1-80, 80.1-90, 90.1-95, 95.1-100.

Using ArcGIS StreetMap USA™ road files (Environmental Systems Research Institute, Inc., 2008), intersection density was computed by dividing the number of three-way or greater intersections by the total length of roads within the buffer (Dill, 2004). Divided highways, ramps, and ferry routes were assumed to be inaccessible to pedestrians and were excluded. Higher values indicate a more connected street network. A four-level categorical variable was created: <2.00, 2.00-3.99, 4.00-5.99, 6.00-11.00 intersections per km of road.

As a proxy measure of land use mix, an overall facility density variable and eight types of facility density variables were created using an InfoUSA™ Business Listing File, a licensed commercial database of facilities current as of January 2006. Facilities constituted a range of private commercial establishments and public services that might serve as walking destinations. The dataset included latitude and longitude and North American Industrial Classification System codes for each facility (U.S. Census Bureau, 2007). Facilities were grouped into eight types: (a) retail (e.g., book store); (b) services (e.g., post office); (c) cultural-educational (e.g., library); (d) physical activity (e.g., fitness center); (e) restaurants (e.g., table service restaurant); (f) fast-food restaurants; (g) food stores (e.g., grocery stores, supermarkets); and (h) convenience stores. Density of facilities was calculated for each of these categories and for all categories combined by dividing the number of facilities by kilometers of road within the residential buffer.

Covariates

To control for potential confounding, the following covariates were included in fully-adjusted models: age in years, race, Hispanic ethnicity, nurse's education, husband's education, BMI (walking models only), walking limitations (yes/no; person reported they were limited a lot or a little walking one to several blocks), feeling more relaxed indoors, and number of years (< 4, 4-10, >10) at current address since 1986. In addition, smoking status was controlled for in overweight/obesity models. Preliminary models also controlled for total caloric intake (kcal/day), but since this variable had no effect on estimates it was not included in final models. All covariates were current as of the 2004 NHS survey, except for nurse's and husband's education, which were obtained in the 1992 survey.

Statistical Analysis

Univariate statistics and bivariate correlations were examined for all variables. In preliminary analyses, relationships between each built environment variable and outcome were modeled using separate restricted cubic spline models to test for non-linearity (Durrleman & Simon, 1989). For walking and overweight/obesity, separate age- and fully-adjusted multivariable logistic regression models were estimated for each built environment variable. Interaction terms were tested and facility density models stratified by population density were estimated. In addition, to examine consistency of relationships between all built environment variables and both outcomes across the three states, stratified models were estimated. All statistical analyses were conducted in SAS version 9 (SAS Institute Inc, Cary, NC) for UNIX.

Results

Sample and Built Environment Characteristics

Participant and environmental characteristics are shown in Table 1. Participants' mean *(SD)* age was 70.0 (6.9) years (range = 57-85). Participants were predominantly white and from well-educated households. Twenty-three percent met the current physical activity recommendation via walking, and 56% were classified as overweight or obese. Mean *(SD)* population density for participants was 1371.5 (1513.9) persons per km^2 of area within 1200 m buffers. Intersection density averaged 4.0 (1.4) intersections per km of road. Mean values for facility density variables ranged from 0.1 (physical activity) to 2.4 (fast-food) facilities per km of road.

Associations with Walking

Differences in results for the 800 m and 1200 m buffer built environment variables were minor; therefore, we only report those for 1200 m. Fully-adjusted logistic regression models controlled for age, number of years living at address, race, ethnicity, husband's and participant's education, BMI, walking limitations, and self-report of feeling more relaxed indoors. Results from age-adjusted spline models (data not shown) indicated a linear relationship between population density and physical activity. In age- and fully-adjusted models, higher population density (units = 1,000 people per km^2) was associated with a 6% (95% CI: 4%, 8%) and 4% (95% CI: 2%, 7%) greater odds of meeting physical activity recommendations via walking, respectively (Table 2). Spline models indicated a non-linear relationship between intersection density and walking. In fully-adjusted models, intersection density in the range of ≥ 2-11 intersections/km compared to < 2 was associated with an 18% (95% CI: 5%, 34%) to 28% (95% CI: 13% to 44%) greater odds of meeting recommendations via walking.

Total facility density and density for six of the eight facility types were associated with greater odds of meeting physical activity recommendations via walking (Table 2). The strongest associations in fully-adjusted models were found for services (e.g., post offices) with an additional facility per km of road associated with a 53% higher odds (95% CI: 20%, 95%). Density of physical activity facilities was associated with a 91% greater odds (95% CI: 33%, 175%) of meeting recommendations via walking in the age-adjusted model, but was greatly attenuated in the fully-adjusted model.

Associations with Overweight/Obesity

Fully-adjusted models for overweight/obesity controlled for age, number of years at address, race, ethnicity, education, walking limitations, more relaxed indoors, and smoking. Population density was not associated with overweight/obesity in the spline models (data not shown) or in the age- and fully-adjusted logistic regression models (Table 2). There was no clear pattern of associations between intersection density and overweight/obesity. In addition, there were few associations with facility density variables. Physical activity facility density was associated with a 44% (95% CI: 23%, 60%) and 31% (95% CI: 4%, 51%) lower odds of overweight/obesity in age- and fully-adjusted models, respectively. Convenience store density showed a positive association with overweight/obesity in the age-adjusted model, but was attenuated in the fully-adjusted model.

Associations with Walking, Stratified by Population Density and State

We found statistically significant interactions between population density and five facility density variables for meeting physical activity recommendations via walking and six facility types for overweight/obesity. Positive associations between facility density variables and the walking outcome were found mostly among women living in the 90.1-95th and 95.1-100th percentiles of population density (Table 3). Six of the eight types of facility density showed positive, statistically significant associations in the 95.1-100th stratum. The overall pattern of associations between population density, intersection density, and facility density variables and walking was comparable across California, Massachusetts, and Pennsylvania (Table 4). Minor exceptions were that there appeared to be an association between intersection density and walking among women in California and Pennsylvania, but not in Massachusetts.

Associations with Weight Status, Stratified by Population Density and State

In overweight/obesity models stratified by population density most statistically significant associations were found for women living in buffers with the highest level of population density (see Table 5). For example, in the highest strata of population density, retail/stores, services, and physical activity facility density were all inversely associated with overweight/obesity – with a one facility per km of road increase in density associated with 14%, 54%, and 89% lower odds of overweight/obesity, respectively. Convenience store density was positively associated with overweight/obesity for women in the 60.1-80th and 90.1-95th percentiles of population density, while restaurant and grocery store density was negatively associated in the highest stratum of population density. Fast food restaurant density was positively associated with overweight/obesity only among women living in the 20.1-40th percentile of population density. Overall, we found few statistically significant associations between built environment variables and overweight/obesity, stratified by state (data not shown). The odds ratios for physical activity facility density among California and Massachusetts participants (0.68 and 0.73, respectively) were similar to the estimate for the non-stratified model, but neither association was statistically significant. However, density of convenience stores was associated with a 17% (95% CI: 5%, 30%) greater odds of being overweight/obese in California.

Discussion

In this study of older women from three U.S. states, we found that higher levels of population density, most categories of facility density variables, and intersection density were associated with greater odds of meeting the current physical activity recommendation via walking. Overall, there were no clear differences in associations with walking by state. Models stratified by population density indicated that density of services, cultural/educational, and physical activity facilities had the strongest positive relationships with the walking outcome among women living in areas with the highest population density. Since this may be one of the most geographically diverse U.S. studies to-date to examine relationships between objective measures of the built environment within residential buffers and walking in older adults, the findings may be relevant to many older women from the Northeast and West regions of the U.S.

Our findings for built environment and walking are generally consistent with previous literature on older adults (Berke et al., 2007; Nagel et al., 2008). For example, in a cross-sectional analysis of 936 men and women, aged 65-97 years from King County, Washington, investigators found a positive association between an objective measure of walkability (i.e., residential density, connectivity, access to facilities) and self-reported walking for exercise (Berke et al., 2007). In another cross-sectional study of 546 older men and women from Portland, Oregon, the number of commercial and other types of destinations (e.g., library, post office) within 402 and 804 m circular buffers was positively associated with total walking time among those who walked, similar to our findings for facility density variables (Nagel et al., 2008).

Our finding that facility density variables were associated with overweight/obesity (mostly in high population density areas) is similar to results reported for land use mix among older adults in Oregon (Li et al., 2008) and another analysis of low income U.S. women where investigators reported that the number of fitness facilities per 1000 residents was inversely associated with BMI (Mobley et al., 2006). Also consistent with literature on adults (Larson & Story, 2009; Morland, Diez Roux, & Wing, 2006), we found that density of grocery stores (which included supermarkets) was associated with lower odds of overweight/obesity for older women living in high population density areas. Alternatively, we found mixed evidence that convenience store density was related to an increased odds of overweight/obesity. This differs from a multi-site study of U.S. adults, ages 49 to 73 years, which found that convenience stores were positively associated with the prevalence of overweight and obesity (Morland et al., 2006). We also found limited evidence for a relationship between fast food restaurant density and overweight/obesity. This finding is in contrast to results from two studies among older Portland, Oregon, adults, which indicated that fast food outlets are associated with a higher prevalence of overweight/obesity (Li et al., 2008) and may increase the risk of weight gain over a one-year period (Li et al., 2009b).

We found limited evidence that population density and intersection density were associated with overweight/obesity. This is consistent with a previous finding that an objective measure of walkability (i.e., residential density, block size) was not associated with BMI in older adults (Berke et al., 2007). In contrast, one recent analysis in a nationally representative sample of U.S. adults, ≥ 55 years of age, determined that street connectivity was associated with 6% lower odds of overweight and obesity among women (Grafova et al., 2008). There are several possible explanations for the lack of evidence of relationships between the built environment within residential buffers and overweight/obesity status. First, overweight/obesity status may be too distal an outcome to detect significant effects. Given that the effects of the built environment on walking (a more proximal outcome) were modest in terms of magnitude, it may be unrealistic to expect to identify significant relationships between the built environment and overweight/obesity in this population. Second, several recent conceptual papers and empirical studies have begun to illustrate the need for a dynamic spatial focus on the built environment that extends beyond the home environment (Cummins, Curtis, Diez-Roux, & Macintyre, 2007; Rodriguez et al., 2012; Troped, Wilson, Matthews, Cromley, & Melly, 2010). For example, for NHS participants who worked for many years in the nursing field, cumulative exposure to the built environment in and around work, may constitute important environmental exposures for physical activity, dietary intake, and ultimately weight status. Third, even though we controlled for length of residence, it is plausible that many study participants falling into the overweight or obese classification had gained most of their weight years earlier and that recent exposures to the built environment were less influential. A longitudinal analysis would be more appropriate for examining effects of the neighborhood built environment on changes in physical activity and the development of overweight and obesity over time.

Our hypothesis that relationships between facility density and walking would vary across levels of population density was generally supported. Findings from previous studies suggest that relationships between built environment attributes and physical activity or obesity vary across urban, suburban, and rural settings (Berrigan & Troiano, 2002; Hou et al., 2010; Joshu, Boehmer, Brownson, & Ewing, 2008). For example, Berrigan and Troiano (2002) found a positive association between home age, a proxy for a constellation of environmental factors that may influence physical activity, and leisure-time walking among residents of urban and suburban counties, but not among those living in rural areas. Investigators in another study found positive associations between street density (i.e., street connectivity) and physical activity in low urban areas and null findings in middle and high urban areas (Hou et al., 2010) – in contrast to our overall findings for facility density variables. To our knowledge, this issue has not been explored with older adults. Our results indicate that a relatively high level of population density is needed for certain environmental attributes, such as access to stores and other facilities, to support walking in older women. These findings indirectly suggest that researchers should possibly examine other types of built environment variables, such as aesthetics, sidewalk coverage, and access to trails and parks, among older residents living in less densely populated areas.

The overall pattern of associations between population, intersection, and facility density variables and walking was similar across the three study states. Despite this finding, it may be advantageous for researchers to continue to explore how geography matters and examine effects of the built environment across diverse geographic units. This type of work could be carried out at different geographic scales, for example, counties within a U.S. state, states within a region, countries, etc. Researchers should not necessarily assume that effects of the built environment will be consistent across different geographies.

We are aware of few studies that have assessed non-linear relationships between built environment variables and physical activity outcomes. This may partially explain inconsistent findings across studies. Using spline models we found that intersection density appears to have a non-linear relationship with walking. Alternatively, Li and colleagues (2008) found positive linear associations between intersection density and four measures of physical activity among middle-aged and older adults. In another study it was found that street connectivity at the neighborhood level was positively associated with walking in older adults (Li et al., 2005). In contrast, investigators in Bogota, Columbia, found that adults 60 years of age and older, who lived in areas with the highest street connectivity, had a 36% lower odds of walking for at least 60 minutes (Gomez et al., 2010). Collectively, these findings for connectivity underscore the importance of considering geographic variability in built environment relationships. Furthermore, the relationship between street connectivity and older adults' physical activity could be evaluated by asking those who live in highly connected neighborhoods about their perceived pedestrian safety. Older adults may feel less safe from traffic in the most highly connected neighborhoods and therefore may be less inclined to walk. Another approach might be to examine differences between pedestrian connectivity (e.g., sidewalks, paths) and vehicle connectivity.

There are several limitations of our study related to the sample, measures, and design. Results may not be generalizable to older women with low education, from racial or ethnic minority groups, or from geographic areas outside of the West and Northeast regions of the U.S. Both the built environment and physical activity measures have limitations. The InfoUSA™ data likely undercount physical activity facilities since it is primarily a business database. It includes private facilities such as health clubs, but schools and community centers where physical activity classes might take place are not listed as such. Therefore, we may have underestimated the true association between physical activity facility density and walking. Also, the walking question was not designed to assess walking for errands or other utilitarian purposes or ascertain whether walking occurred in the person's neighborhood or another location. If the walking item was worded to explicitly measure walking in the neighborhood, we may have found stronger associations between facility density and meeting physical activity recommendations. Also, we did not assess whether participants visited food-related facilities. It is plausible that the effects of fast-food restaurants and convenience stores on overweight/obesity may be restricted to those who routinely use those facilities (Li, Harmer, Cardinal, Bosworth, & Johnson-Shelton, 2009a). The cross-sectional study design precludes making causal inferences about the built environment, walking, and overweight/obesity. Finally, we were not able to examine the relationship between sidewalk availability or condition and walking due to the lack of a consistent data source across the three states. Both presence and condition of sidewalks may affect mobility in older adults; this issue deserves further study.

There are several strengths of our study. We used commercial and public GIS data sources that were available nationwide so that NHS participants in the three states could be studied using standardized measures, diminishing potential bias. This approach has also created the opportunity to extend our work with the cohort to other states using data sources and methods developed in the current study. As noted previously, we view the use of a line-based network buffer around each participant's home as a strength compared to using existing boundaries such as a census tract to define exposure. Also, this type of buffer appears to have an advantage over circular and network polygon buffers (Oliver et al., 2007) by restricting characterization of the built environment to areas in which individuals can move about. We also tested built environment measures for both 800 and 1200 m buffers, as the optimal buffer size is still unknown. In pilot work we examined measures for 400 m buffers among a sub-sample of NHS participants and found only minor difference in values for the intersection density and population density variables for the three buffer sizes. We chose to not proceed with the 400 m buffer because the majority of participants did not have a facility within this buffer size. To our knowledge, only two previous studies have examined multiple buffer sizes with older adults (Berke et al., 2007; Nagel et al., 2008). In one study, investigators found few differences in associations across three buffer sizes: 100, 500, and 1000 meters (Berke et al., 2007). In a second investigation, Nagel and colleagues found statistically significant relationships between built environment factors, such as commercial establishments, and total walking using both 400 and 800 meter buffers (Nagel et al., 2008). As more researchers begin to directly link physical activity behaviors to the built environment with the use of accelerometers and global positioning system devices (Rodriguez, Brown, & Troped, 2005; Troped, Wilson, Matthews, Cromley, & Melly, 2010), the delineation of the appropriate area of "exposure" around home and other locations may become more straightforward.

In conclusion, our findings indicate that for older women with a similar profile to the NHS cohort, built environment attributes may have important relationships with walking and weight status, particularly in more densely populated areas. Though we did not find different relationships between the built environment and key outcomes across three diverse states, researchers may want to continue exploring the role of geographic location on these associations. To promote physical activity and reduce overweight/obesity among older adults, public health researchers and practitioners should include strategies that are focused on the neighborhood built environment. Findings from the current study suggest that neighborhood land use and street design patterns characterized by greater intersection density and density of facilities such as stores, services, cultural/educational, and physical activity facilities may have positive effects on older adults' walking.

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Table 1

Demographic, Health-Related, and Built Environment Characteristics of Participants

	M(SD)	n (%)
Age in years	70.0 (6.9)	
Race		
White		22,762 (97.1)
Black		199 (0.9)
Asian		388 (1.7)
American Indian or Hawaiian		85 (0.4)
Ethnicity		
Hispanic		214 (0.9)
Husband's education		
High school or less		7,811 (43.2)
College graduate		5,418 (30.0)
Graduate school		4,843 (26.8)
Nurse's education		
RN degree only		14,916 (69.9)
College graduate		4,360 (20.4)
Graduate school		2,066 (9.7)
Meeting physical activity recommendations [a]		5,366 (22.9)
Overweight/obesity [b]		12,841 (55.9)
Have a walking limitation		7,692 (32.8)
More relaxed indoors		
Not particularly		18,672 (80.0)
Sometimes		2,876 (12.3)
Definitely		1,779 (7.6)
Smoking status		
Never		10,650 (45.5)
Past		11,128 (47.6)
Current		1,617 (6.9)
Population density [c]	1,371.5(1,513.9)	
Facility density [d]		
Total facilities	1.3(1.6)	
Retail/stores	0.4 (0.6)	
Services	0.1 (0.1)	
Cultural/educational	0.3 (0.3)	
Physical activity	0.1 (0.1)	
Restaurants	0.7(1.4)	
Fast-food restaurants	2.4 (5.0)	
Grocery stores	0.3 (0.6)	
Convenience stores	0.4 (0.6)	

	M(SD)	n (%)
Intersection density [e]		
<2.00		2,154 (9.2)
2.00-3.99		8,995 (38.4)
4.00-5.99		11,015 (47.0)
6.00-11.00		1,270 (5.4)

Note.

[a]Defined as walking ≥ 500 MET-minutes per week.

[b]Defined as body mass index ≥ 25.0, includes overweight and obesity.

[c]Population density is defined as the number of people per km^2 land area in the buffer.

[d]Defined as the number of facilities per km of road in the buffer.

[e]Defined as the number of three-way or greater intersections per km of road in the buffer.

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Table 2

Associations Between Built Environment Variables and Both Meeting Physical Activity Recommendations and Overweight/Obesity

	Meeting PA Recommendations[a] (*N*=23,434; *n* of cases = 5,366)				Overweight/Obesity[b] (*N*=22,961; *n* of cases = 12,841)			
	Model 1[c]		Model 2[d]		Model 1[c]		Model 2[e]	
	OR	95% CI	OR	95% CI	OR	95% CI	OR	95% CI
Population density [f]	1.06	[1.04, 1.08]	1.04	[1.02, 1.07]	0.97	[0.96, 0.99]	0.99	[0.97, 1.01]
Intersection density [g]								
<2.00	1.00	-	1.00	-	1.00	-	1.00	-
2.00-3.99	1.21	[1.08, 1.36]	1.18	[1.05, 1.34]	0.88	[0.80, 0.97]	0.92	[0.83, 1.01]
4.00-5.99	1.27	[1.13, 1.42]	1.28	[1.13, 1.44]	0.93	[0.84, 1.02]	0.97	[0.87, 1.07]
6.00-11.00	1.16	[0.98, 1.37]	1.23	[1.03, 1.48]	1.13	[0.98, 1.30]	1.12	[0.96, 1.30]
Facility density [h]								
Total facilities	1.05	[1.03, 1.07]	1.04	[1.02, 1.07]	0.99	[0.97, 1.01]	0.99	[0.98, 1.01]
Retail/stores	1.11	[1.06, 1.17]	1.10	[1.05, 1.15]	0.97	[0.93, 1.01]	0.98	[0.94, 1.03]
Services	1.58	[1.26, 1.99]	1.53	[1.20, 1.95]	0.84	[0.69, 1.03]	0.89	[0.72, 1.10]
Cultural/educational	1.12	[1.01, 1.25]	1.15	[1.03, 1.28]	1.05	[0.96, 1.15]	1.05	[0.96, 1.15]
Physical activity	1.91	[1.33, 2.75]	1.45	[0.98, 2.15]	0.56	[0.40, 0.77]	0.69	[0.49, 0.96]
Restaurants	1.03	[1.00, 1.05]	1.04	[1.01, 1.06]	1.00	[0.98, 1.02]	1.00	[0.98, 1.02]
Fast-food restaurants	1.02	[1.01, 1.02]	1.01	[1.01, 1.02]	0.99	[0.99, 1.00]	1.00	[0.99, 1.00]
Grocery stores	1.07	[1.02, 1.13]	1.06	[1.00, 1.12]	0.98	[0.94, 1.02]	1.00	[0.95, 1.04]
Convenience stores	1.04	[0.99, 1.09]	1.09	[1.04, 1.15]	1.06	[1.02, 1.10]	1.03	[0.99, 1.07]

Note. OR=odds ratio; CI=confidence interval;

[a] Defined as ≥ 500 MET-minutes/week of self-reported walking.

[b] Defined as BMI ≥ 25. Underweight (BMI < 18.5) participants (n=473) were excluded from overweight/obesity analyses.

[c] Adjusted for age.

[d] Fully-adjusted model controlled for age, number of years at address, race, ethnicity, husband's and nurse's education, body mass index, walking limitations, and more relaxed indoors.

[e] Fully-adjusted model controlled for age, number of years at address, race, ethnicity, husband's and nurse's education, walking limitations, more relaxed indoors, and smoking status.

[f] Units are 1,000 people per km^2 of area within the buffer.

[g] Units are one three-way or greater intersections per km of road within the buffer.

[h] Units are one facility per km of road within the buffer.

Table 3

Fully-Adjusted[a] Associations (OR [95% CI]) Between Facility Density Variables[b] and Meeting Physical Activity Recommendations[c] Stratified by Population Density

	Population density percentile ranges (*n* of cases)						
	0-20.0th (*1053*)	**20.1-40.0th (*1102*)**	**40.1-60.0th (*1072*)**	**60.1-80.0th (*1064*)**	**80.1-90.0th (*511*)**	**90.1-95.1th (*272*)**	**95.1-100th (*292*)**
Total facilities	1.13 [0.98, 1.31]	1.00 [0.92, 1.08]	1.03 [0.96, 1.10]	0.99 [0.94, 1.05]	0.98 [0.91, 1.06]	1.16 [1.07, 1.26]	1.08 [1.04, 1.13]
Retail/stores	1.38 [0.95, 2.02]	0.98 [0.81, 1.20]	1.04 [0.90, 1.21]	0.98 [0.87, 1.11]	0.98 [0.83, 1.16]	1.36 [1.15, 1.61]	1.18 [1.05, 1.33]
Services	1.20 [0.35, 4.20]	0.84 [0.42, 1.71]	1.29 [0.70, 2.38]	1.10 [0.61, 1.96]	0.60 [0.26, 1.39]	2.08 [0.69, 6.28]	3.81 [2.04, 7.12]
Cultural/educational	1.08 [0.65, 1.80]	0.91 [0.64, 1.28]	1.15 [0.83, 1.58]	0.83 [0.61, 1.13]	0.80 [0.52, 1.23]	1.48 [0.83, 2.64]	1.45 [1.12, 1.88]
Physical activity	1.40 [0.44, 4.46]	1.30 [0.54, 3.14]	0.66 [0.25, 1.76]	0.79 [0.32, 1.95]	0.57 [0.16, 2.08]	14.56 [2.54, 83.31]	8.18 [2.13, 31.51]
Restaurants	1.11 [0.97, 1.27]	0.99 [0.92, 1.06]	.1.02 [0.96, 1.08]	1.02 [0.97, 1.08]	0.98 [0.91, 1.05]	1.11 [1.01, 1.22]	1.09 [1.01, 1.18]
Fast-food restaurants	1.07 [1.00, 1.13]	1.02 [0.99, 1.06]	1.01 [0.98, 1.04]	1.00 [0.98, 1.02]	0.99 [0.97, 1.02]	1.03 [1.00, 1.06]	1.01 [1.01, 1.02]
Grocery stores	1.00 [0.82, 1.22]	1.01 [0.86, 1.19]	1.00 [0.87, 1.15]	1.02 [0.91, 1.15]	1.09 [0.91, 1.30]	1.11 [0.88, 1.39]	1.09 [0.95, 1.26]
Convenience stores	1.18 [1.00, 1.40]	1.09 [0.97, 1.24]	1.12 [0.99, 1.26]	0.98 [0.86, 1.12]	0.99 [0.82, 1.19]	1.27 [1.03, 1.58]	1.05 [0.94, 1.17]

Note. OR=odds ratio; CI=confidence interval;

[a]Fully-adjusted for age, race, ethnicity, nurse's education, husband's education, body mass index, - walking limitations, more relaxed indoors, and number of years living at present address.

[b]Defined as the number of facilities per km of road within the buffer.

[c]Defined as walking ≥ 500 MET-minutes/week.

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Table 4

Fully-Adjusted[a] Associations Between Built Environment Variables and Meeting Physical Activity Recommendations[b] Stratified by State

	California *N*=7,709 *n* of cases = 1,978		Massachusetts *N*=5,428 *n* of cases = 1,303		Pennsylvania *N*=10,297 *n* of cases = 2,085	
	OR	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Population density[c]	1.05	[1.01, 1.09]	1.04	[1.01, 1.08]	1.01	[0.97, 1.05]
Intersection density[d]						
<2.00	1.00	-	1.00	-	1.00	-
2.00-3.99	1.18	[0.91, 1.54]	1.08	[0.85, 1.38]	1.21	[1.02, 1.44]
4.00-5.99	1.33	[1.03, 1.72]	1.17	[0.91, 1.50]	1.18	[0.99, 1.40]
6.00-11.00	1.31	[0.83, 2.10]	1.18	[0.81, 1.71]	1.29	[1.01, 1.63]
Facility density[e]						
Total facilities	1.04	[1.01, 1.07]	1.05	[1.01, 1.09]	1.03	[0.99, 1.07]
Retail/stores	1.07	[1.00, 1.14]	1.11	[0.99, 1.25]	1.07	[0.96, 1.19]
Services	1.70	[1.18, 2.47]	1.41	[0.88, 2.27]	1.40	[0.89, 2.19]
Cultural/educational	1.21	[1.00, 1.46]	1.22	[1.01, 1.48]	1.07	[0.88, 1.29]
Physical activity	1.25	[0.69, 2.25]	1.60	[0.75, 3.41]	0.98	[0.46, 2.08]
Restaurants	1.02	[0.99, 1.06]	1.04	[0.98, 1.10]	1.04	[1.00, 1.08]
Fast-food restaurants	1.01	[1.00, 1.02]	1.02	[1.00, 1.03]	1.01	[0.99, 1.02]
Grocery stores	1.09	[1.00, 1.18]	1.10	[0.97, 1.25]	0.96	[0.87, 1.06]
Convenience stores	1.13	[1.00, 1.28]	1.09	[1.01, 1.17]	1.12	[1.03, 1.22]

Note.

[a]Fully-adjusted model controlled for age, number of years at address, race, ethnicity, husband's and nurse's education, body mass index, walking limitations, and more relaxed indoors.

[b]Defined as ≥ 500 MET-minutes/week of self-reported walking.

[c]Units are 1,000 people per km^2 of area within the buffer.

[d]Units are one three-way or greater intersections per km of road within the buffer.

[e]Units are one facility per km of road within the buffer.

Table 5

Fully-Adjusted[a] Associations (OR [95% CI]) Between Facility Density Variables[b] and Overweight/Obesity[c] Stratified by Population Density

	Population density percentile ranges *(n of cases)*						
	0-20.0th *(2622)*	**20.1-40.0th** *(2638)*	**40.1-60.0th** *(2621)*	**60.1-80.0th** *(2504)*	**80.1-90.0th** *(1225)*	**90.1-95.0th** *(609)*	**95.1-100th** *(622)*
Total facilities	0.98 [0.87, 1.11]	1.07 [1.00, 1.14]	1.04 [0.98, 1.10]	1.03 [0.98, 1.08]	0.98 [0.92, 1.04]	0.94 [0.87, 1.00]	0.94 [0.90, 0.98]
Retail/stores	0.94 [0.67, 1.30]	1.15 [0.97, 1.35]	1.08 [0.95, 1.23]	1.04 [0.94, 1.14]	0.98 [0.85, 1.13]	0.86 [0.74, 1.00]	0.86 [0.77, 0.97]
Services	0.65 [0.23, 1.86]	1.36 [0.76, 2.46]	1.48 [0.89, 2.46]	1.09 [0.67, 1.77]	0.63 [0.32, 1.27]	0.40 [0.17, 0.97]	0.46 [0.27, 0.80]
Cultural/educational	1.23 [0.81, 1.86]	1.19 [0.89, 1.59]	1.27 [0.98, 1.66]	1.28 [1.00, 1.65]	0.79 [0.55, 1.13]	0.90 [0.55, 1.45]	0.83 [0.65, 1.04]
Physical activity	0.74 [0.28, 2.02]	1.18 [0.55, 2.54]	0.59 [0.27, 1.29]	1.34 [0.64, 2.77]	0.42 [0.15, 1.19]	0.21 [0.05, 0.92]	0.11 [0.03, 0.39]
Restaurants	0.94 [0.83, 1.06]	1.03 [0.97, 1.09]	1.03 [0.98, 1.08]	1.03 [0.99, 1.08]	0.98 [0.93, 1.04]	0.98 [0.91, 1.06]	0.91 [0.85, 0.97]
Fast-food restaurants	1.00 [0.95, 1.05]	1.04 [1.01, 1.07]	1.02 [1.00, 1.04]	1.01 [0.99, 1.03]	1.00 [0.98, 1.03]	0.98 [0.96, 1.01]	0.99 [0.98, 1.00]
Grocery stores	1.20 [0.99, 1.46]	1.04 [0.91, 1.20]	1.01 [0.90, 1.14]	0.99 [0.90, 1.08]	1.01 [0.87, 1.18]	0.92 [0.77, 1.11]	0.88 [0.77, 1.00]
Convenience stores	0.97 [0.84, 1.13]	1.03 [0.93, 1.14]	0.95 [0.86, 1.06]	1.12 [1.00, 1.25]	1.12 [0.96, 1.30]	1.21 [1.01, 1.45]	0.95 [0.86, 1.06]

Note. OR=odds ratio; CI=confidence interval;

[a] Fully-adjusted for age, race, ethnicity, nurse's education, husband's education, walking limitations, more relaxed indoors, number of years living at present address, and smoking status.

[b] Defined as the number of facilities per kilometer of road within the buffer.

[c] Defined as BMI > 25.0, includes overweight and obesity.