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Direct and Indirect Associations between the Built Environment and Leisure and Utilitarian Walking in Older Women

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Abstract

Background—The built environment predicts walking in older adults, but the degree to which associations between the objective built environment and walking for different purposes are mediated by environmental perceptions is unknown.

Purpose—We examined associations between the neighborhood built environment and leisure and utilitarian walking and mediation by the perceived environment among older women.

Methods—Women (N=2,732; M_{age}=72.8± 6.8 years) from Massachusetts, Pennsylvania, and California completed a neighborhood built environment and walking survey. Objective population and intersection density and density of stores and services variables were created within residential buffers. Perceived built environment variables included measures of land use mix, street connectivity, infrastructure for walking, aesthetics, traffic safety, and personal safety. Regression and bootstrapping were used to test associations and indirect effects.

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Results—Objective population, stores/services, and intersection density indirectly predicted leisure and utilitarian walking via perceived land use mix (odds ratios (ORs)=1.01–1.08, 95% bias corrected and accelerated confidence intervals do not include 1). Objective density of stores/services directly predicted ≥150 minutes utilitarian walking (OR=1.11; 95% CI=1.02, 1.22). Perceived land use mix (ORs=1.16–1.44) and aesthetics (ORs=1.24–1.61) significantly predicted leisure and utilitarian walking,

Conclusions—Perceived built environment mediated associations between objective built environment variables and walking for leisure and utilitarian purposes. Interventions for older adults should take into account how objective built environment characteristics may influence environmental perceptions and walking.

Keywords

Physical activity; Exercise; Neighborhood; Perceptions; Mediator; Older adults

Introduction

Despite the well-documented benefits of physical activity for older adults in terms of lower risk of chronic diseases and improved functional outcomes (1), seniors are the least active segment of the population (2, 3). Furthermore, trends in physical activity among older adults have improved little in recent years. For example, the proportion of US adults ages 65 and older meeting recommendations for moderate physical activity remained at around 33% between 2005 and 2009 (4). Public health initiatives to promote physical activity among older adults may have a greater likelihood of success if they target moderate intensity physical activities that can be performed in a variety of locations, require little skill and are relatively safe to perform (5, 6). Walking for leisure and utilitarian (e.g., active travel) purposes clearly meet these requirements. Indicative of its appeal as a routine activity, walking is the most common type of physical activity reported by older adults (7, 8).

Consistent with social ecological models of health promotion (9–12), attributes of the neighborhood built environment, including residential and population density, land use mix, and street connectivity, have been found to be positively associated with various physical activity outcomes, including active commuting, in older adults in the U.S. (13–16) and internationally, such as in Japan (17), China (18), and Great Britain (19). A smaller number of studies have specifically focused on relationships between the built environment and walking among older adults. One study in Portland, Oregon demonstrated that among seniors who engaged in some walking, an objective measure of the number of commercial establishments in their neighborhood was positively associated with weekly duration of walking (15). Li and colleagues found positive associations between objective housing density, street intersections, and recreational spaces and neighborhood walking (20). In a study of women (M_{age}=57 years) from the Pittsburgh, Pennsylvania area, objectively-assessed proximity to businesses and facilities (e.g., within walking distance of a post office) and a proxy measure of urban form (i.e., neighborhood with homes built between 1950 and 1969) had statistically significant positive relationships with pedometer steps (14). However, these studies did not separate walking performed for leisure and travel purposes and therefore could not determine whether environmental factors associated with these two forms of walking differed. Several recent studies from Belgium (21), Brazil (22), and Japan (23) examined built environment correlates of walking for different purposes. Van Holle and colleagues found that an objective, GIS-derived measure of neighborhood walkability was positively associated with transport-related walking among older Belgian adults, but not with recreational walking (21). Investigators in Brazil also found different associations between built environment variables and walking for transport and leisure among older adults; with significant associations between objective measures of population density, street connectivity, sidewalks and paved streets and walking for transport; and only a significant association between street density and walking for leisure(22). One study of older adults in Japan (23) found that the perceived social environment and aesthetics were positively associated with both travel-related and recreational walking. However, two additional self-reported environmental variables, bicycle lanes and access to exercise facilities, were related to walking for travel only. Furthermore, among older women in this study, aesthetics was associated with recreational, but not with travel-related walking (23). Since current U.S. public health objectives focus on increasing both leisure and utilitarian forms of walking (24), developing a better understanding of the environmental factors associated with these different physical activity behaviors is relevant to national health promotion efforts.

Social ecological frameworks also suggest that influences on physical activity at more distal levels such as the built environment can influence behavior via their effect on more proximal variables such as individual-level characteristics (10). One mechanism by which objective neighborhood built environment characteristics may affect behaviors is by influencing individuals' perceptions of their neighborhood. If an individual perceives built environment conditions to be more favorable for walking, this perception of the environment should account, at least in part, for the effect of the objective environmental factors on that person's walking behavior. Environmental psychologists also espouse the idea that objective physical environmental factors interact with individual-level factors, such as sociodemographic characteristics and perceptions of the environment, to influence behavior (25). While there is evidence that both perceived and objective built environment variables are related to physical activity in older adults, there is a need to examine the degree to which objective features of the built environment are associated with walking both directly and indirectly via perceptions of the neighborhood environment in order to develop more effective interventions. To our knowledge, only one study has examined mediation by individual perceptions of the built environment in women (M_{age}= 34.6 ± 8.2 years) who were living in socioeconomically disadvantaged neighborhoods in Australia (26), and no studies have explored this issue in older U.S. women.

Therefore, the aim of this study was to examine direct and indirect effects of the built environment on leisure and utilitarian walking among older women in three U.S. states. The main hypothesis was that effects of the objective built environment on walking would be mediated by individual perceptions of the environment. A secondary hypothesis was that objective and perceived environmental predictors would differ for leisure and utilitarian walking.

Methods

Design and Participants

This study employed a cross-sectional design to examine associations between the built environment and walking outcomes. Participants were drawn from the Nurses' Health Study (NHS), a prospective cohort study that began in 1976 with 120,700 female nurses from eleven U.S. states. At the time of enrollment, women were 30–55 years of age. A random sample of 3,900 NHS participants from Massachusetts, Pennsylvania, and California were selected to participate in a supplemental survey measuring perceptions of the neighborhood built environment and walking for different purposes. Inclusion criteria for the survey were that the participant: 1) lived in California, Massachusetts, or Pennsylvania from 2004–2008; 2) was an early respondent to the 2008 NHS biennial questionnaire (completed the first survey sent out that year; follow-up surveys are sent to nonrespondents); and 3) had a geocoded home address at the street segment level. Eighty-four percent of women ($N =$ 3,277) returned a survey after one mailing in 2009. Survey respondents in the final analytic sample ($n = 2{,}732$) met the following requirements: 1) were able to walk; 2) lived at their address at least nine months of the year and during the four weeks prior to the survey; 3) had complete data for living situation and lived in a noninstitutional setting; and 4) had complete data for walking limitations, built environment and walking items. This sample also excluded 64 individuals with outlying values for walking and built environment variables. The institutional review boards at Purdue University, the Brigham and Women's Hospital, and the Harvard School of Public Health approved study procedures.

Measures

Walking outcomes.—Using items derived from the Community Healthy Activities Model Program for Seniors (CHAMPS) survey (27), participants were asked three questions about walking outdoors for leisure: "In a typical week during the past 4 weeks, how many times did you": 1) walk leisurely for exercise or pleasure outdoors; 2) walk fast or briskly for exercise outdoors (do not count walking leisurely or uphill); 3) walk or hike uphill outdoors (count only uphill part). Using the same format, participants were also asked to report on two types of outdoor walking for utilitarian purposes: 1) walk to do errands (such as to and from a store); 2) walk to visit friends, family or neighbors. For each walking item, respondents were asked to report total time engaged in the activity in a typical week using the following response options: <1 hour/week, 1–2.5 hours/week, 3–4.5 hours/week, 5–6.5 hours/week, 7–8.5 hours/week, and ≥9 hours/week. These categories were converted into the following discrete values (most were equal to the midpoint of the range): 30, 105, 225, 345, 465, and 585 minutes per week, respectively (27). Responses for the three leisure and the two utilitarian walking items were summed together to derive weekly minutes of walking for leisure and utilitarian purposes, respectively. Skew statistics for leisure and utilitarian walking minutes indicated non-normal distributions for both variables. Therefore, two binary ("yes/no") outcomes were created for each type of walking: "any" walking versus none and ≥150 minutes of walking per week versus <150 minutes (current guidelines for aerobic activity in adults).

Perceived built environment.—Perceptions of the neighborhood built environment were measured with items from a modified version of the Abbreviated Neighborhood Environment Walkability Scale (ANEWS) (28). This version of ANEWS has the same 6-factor structure as the original ANEWS, but has 19 items as compared to 24 items in the original instrument. This change was based on prior work with older adult women demonstrating that the 19-item, 6-factor version had better psychometric properties than the 24-item version (29).

The modified ANEWS has 19 items in six subscales: land use mix (access to destinations; 3 items), street connectivity (2 items), infrastructure for walking (4 items), aesthetics (4 items on trees, attractiveness of natural surroundings and buildings, and interesting things to view), traffic safety (3 items), and personal safety (3 items). Items in each subscale were measured with 4-point Likert-scales ranging from one (strongly disagree) to four (strongly agree) with higher scores indicating a more favorable perception of the neighborhood walking environment. Items were reverse scored as needed. Similar subscales from the Neighborhood Environment Walkability Scale (NEWS) have shown good test-retest reliability with intraclass correlation coefficients ranging from 0.58 to 0.80 (30). Construct and factorial validity of the 6-factor structure of ANEWS has been supported in previous studies (28, 29, 31).

Objective built environment.—Geographic information systems (GIS) procedures and data sources for objective built environment variables were recently described in more detail (32). Variables were created in three domains, density, street connectivity, and land use mix, using a 1200-meter line-based network buffer (33) around each participant's geocoded home address. Use of a 1200-meter buffer compared to using a smaller buffer size (400 or 800 meter) has been supported in previous studies with the Nurses' Health Study cohort (32, 34). Population density was created using LandScan™ data (35) and was calculated as the number of persons per square kilometer of area within the buffer. Using ArcGIS StreetMap USA™ road files (Environmental Systems Research Institute, Inc.) (36), intersection density was computed by dividing the number of three-way or greater intersections by the total length of roads within the buffer (37). Divided highways, ramps, and ferry routes were assumed to be inaccessible to pedestrians and were excluded. To approximate land use mix, density of stores and facilities variable was created using an InfoUSA™ Business Listing File. Recent research has supported the use of these commercial data to characterize the built environment (38). Facilities constituted a range of private commercial establishments and public services that might serve as walking destinations. These included places such as book stores, post offices, libraries, fitness centers, fast-food and sit-down restaurants, grocery stores, supermarkets, and convenience stores. Overall facility density was calculated by dividing the number of facilities by kilometers of road within the residential buffer.

Covariates.—Data on potential confounders were obtained from the NHS biennial surveys. These covariates included age in years, race (White, Black, Asian, American Indian or Hawaiian), Hispanic ethnicity, nurse's education (registered nurse (RN) only, bachelor's, master's or doctoral degree), walking limitations (yes/no; respondent reported they were limited a lot or a little walking one to several blocks), and weight categories derived from body mass index (BMI) (weight (kg)/[height (m)]^2). The four categories were underweight (<18.5), normal (18.5–24.9), overweight (25.0–29.9) and obese (≥30.0) (39). All information on covariates was collected in the 2008 NHS survey, except for nurse's height, which was obtained in 1976, education, which was assessed in 1992, and race and ethnicity, assessed both in 1992 and 2004.

Statistical Analyses

All statistical analyses were conducted in SAS version 9.2 (SAS Institute Inc., Cary, NC). Means and frequencies were calculated for covariates, environmental variables, and walking outcomes, overall and by state. Separate multiple logistic regression models were used to examine whether the three objective built environment variables predicted leisure and utilitarian walking, and whether these associations were mediated by the six perceived environment variables; one model for each walking outcome. Models controlled for age, race, Hispanic ethnicity, nurse's education, walking limitations, and weight categories.

We used multiple logistic regression to test whether objective and perceived environment variables predicted leisure and utilitarian walking, and 95% bias corrected and accelerated confidence intervals generated using bootstrap resampling methods ($k = 10{,}000$) to test whether there were significant indirect effects (i.e., mediation) of the objective environment variables on walking via the perceived environment variables (40, 41). The bootstrapping method was chosen for testing mediation since it provides an inferential test of indirect effects of the independent variables on the dependent variables via the mediating variables, does not require a normal sampling distribution, has greater statistical power than the traditional causal steps approach for testing mediation, and reduces Type I errors (40). Cases in which the 95% bias corrected and accelerated confidence interval of the indirect effect did not include 1 were interpreted as mediators of the effects of objective built environment variables on walking (41).

Results

Sample Characteristics and Unadjusted Associations

Participants' mean age was 72.8 years with a range of 61.5 to 88.4 years (see Table 1). The average age for California participants was about 4 years greater than that for women from Massachusetts and Pennsylvania. Overall, the sample was predominantly White, though California participants were slightly more racially diverse. The highest proportion of women with a RN degree only (i.e., lower education) was found in Pennsylvania, followed by Massachusetts, and California. The proportion of participants who were either overweight or obese approached 50%. Mean BMI was highest for women from Pennsylvania (27.4±5.5), followed by Massachusetts (26.1±5.0) and California (25.1±4.8). The proportion of women reporting walking limitations was highest in California. Overall, 56% of participants met current physical activity recommendations based on leisure walking only; this proportion was 6% higher when utilitarian walking was included (data not shown). Median weekly minutes of walking for leisure was highest in California, followed by Massachusetts, and significantly lower in Pennsylvania compared to the other two states. The same pattern of state differences held true for utilitarian walking.

Correlations between objective and perceived built environment variables are shown in Table 2. Objective population density had moderate correlations with objective stores/services density ($r = 0.66$) and intersection density ($r = 0.51$). Among the six perceived environment subscales, walking infrastructure and land use mix had the strongest correlations with the three objective built environment variables (all $r \geq 0.31$). Perceived street connectivity also showed a moderate correlation with objective intersection density ($r = 0.42$). Correlations between three specific perceived built environment variables, infrastructure, street connectivity, and land use mix, were all ≥0.41.

In unadjusted logistic regression models, objective population density, intersection density, and density of stores/services did not show statistically significant associations with either leisure walking outcome. However, these three variables had significant positive associations with "any" and ≥150 minutes of utilitarian walking with odds ratios ranging from 1.11 to 1.20.

Effects of Objective Built Environment on Physical Activity, Mediated by Perceived Environment Variables—Tables 3 and 4 show the indirect effects of the objective built environment variables on leisure and utilitarian walking via the perceived built environment. In other words, these tables show results for the models with the objective built environment predicting four different walking outcomes, mediated by the perceived environment. As hypothesized, there were significant, positive indirect effects of all three objective built environment variables on leisure walking ("any" and ≥ 150 minutes/week) via perceived land use mix (see Table 3). These findings indicated that perceived land use mix mediated the associations between objective built environment and walking for leisure. Specifically, participants who lived in neighborhoods (defined by 1200-meter residential buffers) with greater population, stores/services, and intersection density tended to have more positive perceptions of the ease of walking to stores, transit stops, and other destinations (perceived land use mix), which predicted a greater likelihood of participating in "any" and ≥ 150 minutes/week leisure walking. The magnitude of the significant indirect effects was relatively small with odds ratios ranging from 1.01 to 1.05.

As shown in Table 4, all three objective built environment variables showed statistically significant, positive indirect effects with "any" and ≥150 minutes of utilitarian walking via perceived land use mix, providing evidence that perceived land use mix was a significant mediator. Again, participants living in neighborhoods with greater population, stores/services, and intersection density tended to have more positive perceptions of the ease of walking to stores, transit stops and other destinations, which in turn predicted a greater likelihood of them engaging in some utilitarian walking and meeting physical activity recommendations through utilitarian walking. Similar to the findings for leisure walking, the magnitude of indirect effects on utilitarian walking was small with odds ratios ranging from 1.02 to 1.08.

As shown in Figure 1, after accounting for the other variables in the model, objective density of stores/services had a statistically significant positive association with ≥150 minutes of utilitarian walking. More positive perceptions of aesthetics significantly and directly predicted any leisure and utilitarian walking and ≥150 minutes of leisure walking.

Participants' perceptions of greater land use mix also significantly and positively predicted all four walking outcomes, accounting for the other variables in the model. Odds ratios for significant direct effects on walking outcomes ranged from 1.11 to 1.61.

Discussion

The main hypothesis of this study, that perceptions of the built environment would mediate effects of the objective built environment, received some empirical support. Overall, we found evidence that the objective built environment's effects on leisure and utilitarian walking among older women may operate via effects on an individual's perceptions of their neighborhood environment. Older women living in residential buffers with greater population density, density of stores/services, and intersection density consistently had more positive perceptions of land use mix, and those perceptions in turn predicted more leisure and utilitarian walking. A secondary hypothesis that built environment variables associated with leisure and utilitarian walking would differ received limited support; predictors of these two forms of walking were generally similar.

Despite the hundreds of studies published in the past 10–15 years on the built environment and physical activity, only a small number have explored mediation pathways in terms of effects of the built environment on physical activity (26, 42–45). In the only study we are aware of that examined mediating effects of the perceived built environment on relationships between the objective built environment and walking, Van Dyck and colleagues investigated associations in over 4000 adult women residing in socioeconomically disadvantaged neighborhoods in Victoria, Australia (26). Specifically, the researchers tested mediating effects of perceived aesthetics, the neighborhood physical activity environment (e.g., opportunities and facilities for physical activity, ease of walking, and seeing others walk or exercise), personal safety, and neighborhood social cohesion, on the effects of a combined objective measure of destinations/connectivity on both leisure and transport-related walking. Key findings were that aesthetics, personal safety, and social cohesion were statistically significant mediators for leisure walking and that the physical activity environment was a significant mediator for transport-related walking. These findings differ from the present study, in which we did not find evidence of mediation by perceived aesthetics or personal safety for leisure walking. However, there is some consistency in findings for utilitarian walking, whereby the physical activity environment scale and land use mix were significant mediators in the two studies. Despite differences in methods, the two studies provide initial empirical support for a conceptual framework in which objective features of the built environment influence individual environmental perceptions – which in turn affect walking.

A secondary hypothesis of this study was that built environment predictors of leisure and utilitarian walking would differ. This study found little evidence of differences between predictors of leisure and utilitarian walking. The land use mix measure, which assessed individuals' perceptions about stores, transit stops, and other destinations within walking distance of home, was significantly associated with all four measures of leisure and utilitarian walking; consistent with a previous study in Washington state (46). Perceived aesthetics showed significant direct effects with three walking outcomes; these results generally diverge from more equivocal findings from previous studies with older adults (16, 46, 47).

This study has several limitations. First, given the cross-sectional design, we cannot determine the direction of effects. However, we tested models with alternate directions of effects (i.e., perceived environment predicting objective environment predicting physical activity) and found no evidence of mediation by objective built environment variables. Second, although the walking questions specified "outdoor" activity, the items did not specifically ask women to report on walking performed in their neighborhood. It is possible that stronger effects may have been found using a neighborhood walking outcome, since the built environment measures would be more closely linked to the locations where women actually walked. Third, the participants in this study are former nurses who are predominantly White, middle to upper SES, and older. Therefore, the results may not be applicable to younger age groups, to older U.S. women who are more racially or ethnically diverse or of lower SES, or to women who have not worked in the healthcare field. Finally, use of a self-report measure of physical activity is a limitation. Participants likely over-reported their walking and therefore the estimates for meeting guidelines may be high; though they are generally consistent with those from national data for older adults in the U.S.(4). Strengths of this study include: testing associations with both leisure and utilitarian walking; testing mediational pathways not previously explored in built environment studies; and examining a sample of adult women that live in three different geographic regions of the U.S.

Our mediation findings conceptually support a pathway between objective features of the neighborhood built environment, residents' perceptions of those factors, and their engagement in walking for different purposes. That we found significant indirect and direct effects has important implications for community-based physical activity interventions. These findings suggest that design or redesign of neighborhoods to support walking should be combined with behavioral strategies to enhance individuals' perceptions of neighborhood walkability. This intervention approach is consistent with recommendations by the Community Preventive Services Taskforce (37). Further work is needed to explore the relative emphasis that should be placed on objective and perceived environmental factors when designing interventions, an issue that has potential policy implications (e.g., decisions on funding for infrastructure improvements versus educational/promotional activities).

Consistent with a key principle of social ecological models, future built environment studies could incorporate and test mediating effects of individual-level theoretical constructs. Recent studies have shown that constructs such as subjective norms, attitudes, and perceived behavioral control, may lie on the causal pathway between individual perceptions of neighborhood environment and physical activity (44, 45). Prior studies have posited that perceptions of the neighborhood environment influence cognitive factors such as attitudes, which in turn influence physical activity – but it is plausible that constructs such as this influence environmental perceptions. As environmental psychologist Jack Nasar noted, research on human perceptions of neighborhood environments is less advanced than the use of objective built environment measures (25).

Findings from this study are relevant to the U.S. Surgeon General's campaign to promote walking and walkable communities (48), since a better understanding of the interrelationships between perceived and objective measures of the built environment and walking could inform the development of more effective interventions. Despite the fact that several built environment approaches are now recommended for promoting physical activity (49, 50), the specific pathways by which objective and perceived environmental factors influence physical activities, such as walking, are poorly understood. This study's findings are also relevant to Healthy People 2020 objectives for increasing the prevalence of walking for both leisure and travel-related purposes among adults (24). To more effectively promote walking in older adults, practitioners and researchers should consider strategies that reflect the potential direct and indirect effects of environmental factors on walking behaviors. In addition, urban planners, landscape architects, and transportation planners who are attempting to improve neighborhood walkability should assess older adults' perceptions of their neighborhoods, including the use of focus groups and other qualitative methods to assess perceptions of plans before they are implemented. Clearly environmental perceptions seem to matter in terms of older adults' walking behaviors.

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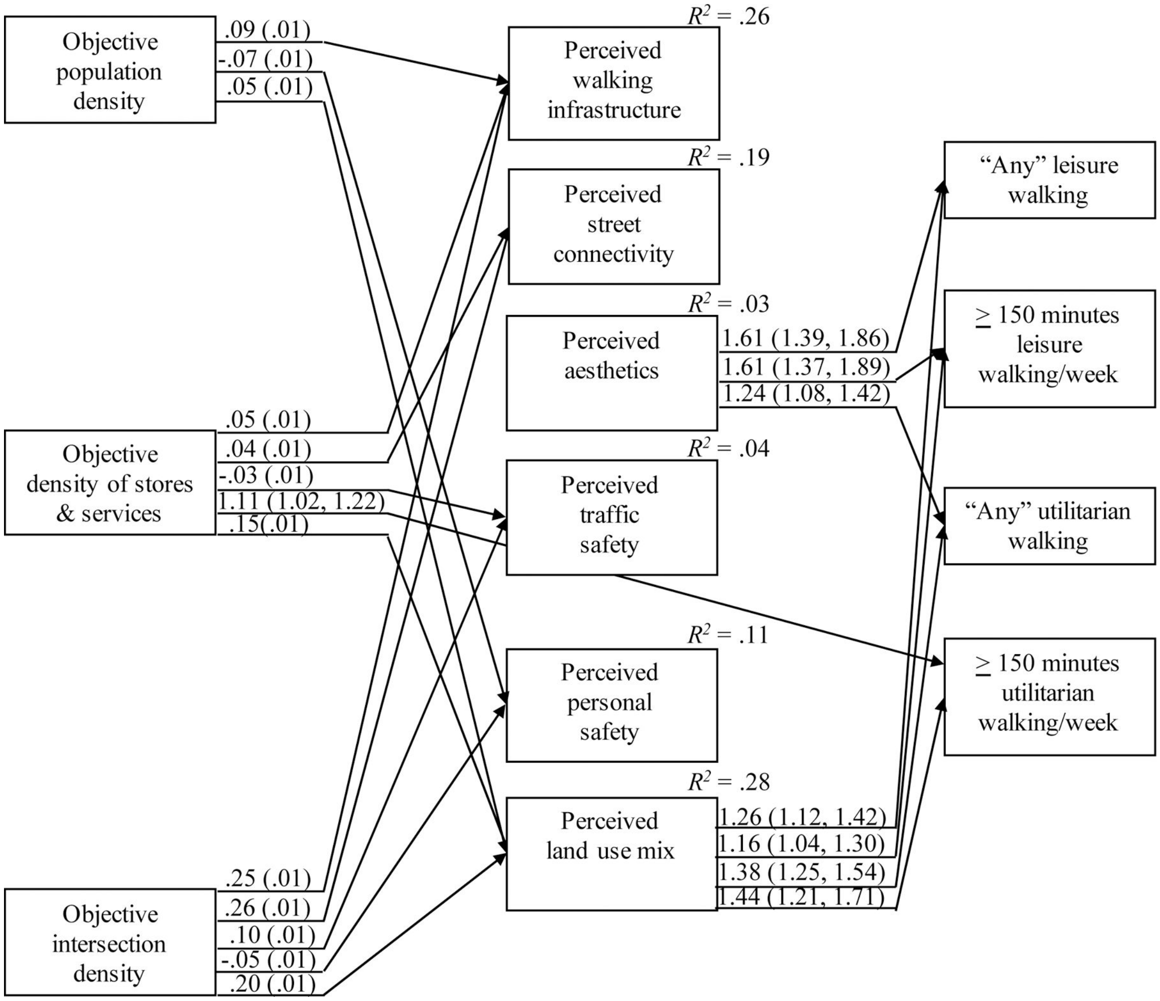

Figure 1.

Model of objective and perceived built environment variables on leisure and utilitarian walking among 2,732 Nurses' Health Study participants from California, Massachusetts, and Pennsylvania. Note: RMSEA = .07, CFI = .86, SRMR = .09; Model included all possible paths from objective built environment variables to perceived built environment variables, and objective and perceived built environment variables to physical activity outcomes, but only significant relationships (p<.05) are shown for clarity. Direct effects with walking outcomes are expressed as odds ratios and 95% confidence intervals. Coefficients are unstandardized regression coefficients (*SE*). Model adjusted for age, race, Hispanic ethnicity, education, walking limitations, and BMI categories.

Table 1

Demographic, health-related and walking characteristics of a subsample of 2,732 Nurses' Health Study participants from California, Massachusetts, and Pennsylvania surveyed in 2008

Characteristics	Overall N = 2,732	California n=917	Massachusetts n=919	Pennsylvania n=896
Age in years (*M* (SD))	72.8 (6.8)	75.5 (6.5)	71.6 (6.5)	71.4 (6.6)
Race (% (n))				
White	97.3 (2658)	93.0 (853)	99.8 (917)	99.1 (888)
Asian	1.5 (42)	4.5 (41)	0.2 (2)	0.7 (6)
Black	1.0 (26)	2.0 (18)	0.0 (0)	0.1 (1)
American Indian/Hawaiian	0.2 (6)	0.6 (5)	0.0 (0)	0.1 (1)
Hispanic ethnicity (% (n))	0.8 (21)	1.7 (16)	0.3 (3)	0.2 (2)
Education (% (n))				
RN degree only	63.1 (1723)	54.0 (495)	63.9 (587)	71.5 (641)
Bachelor's degree	21.2 (578)	27.8 (255)	20.2 (186)	15.3 (137)
Master's degree	9.3 (254)	11.9 (109)	9.6 (88)	6.4 (57)
Doctoral degree	1.1 (29)	1.3 (12)	1.1 (10)	0.8 (7)
Missing	5.4 (148)	5.0 (46)	5.2 (48)	6.0 (54)
Weight status (% (n))				
Underweight (BMI<18.5)	2.5 (68)	3.6 (33)	2.3 (21)	1.6 (14)
Normal (BMI: 18.5–24.9)	40.4 (1103)	46.9 (430)	40.7 (374)	33.4 (299)
Overweight (BMI: 25–29.9)	30.9 (843)	28.2 (259)	32.0 (294)	32.4 (290)
Obese (BMI ≥ 30)	18.7 (512)	13.0 (119)	17.4 (160)	26.0 (233)
Missing	7.5 (206)	8.3 (76)	7.6 (70)	6.7 (60)
Walking limitations (% (n))				
Yes, a lot	36.8 (1006)	38.6 (354)	34.9 (321)	36.9 (331)
No, not at all or yes, a little	63.2 (1726)	61.4 (563)	65.1 (598)	63.1 (565)
Leisure walking min/week[a] (*M* (SD))	135.9 (162.0)	151.1 (158.1)	141.5 (165.5)	114.4 (160.2)
Utilitarian walking min/week[b] (*M* (SD))	53.9 (81.2)	59.0 (80.7)	56.1 (84.5)	46.3 (77.7)

Note. There were statistically significant differences in age, Hispanic ethnicity, education, the amount of leisure and utilitarian walking, and weight categories by state; all p values < 0.01. The percentage of women with walking limitations did not differ significantly across the three states. Cell sizes were too small to test for differences in race by state.

[a]Sum of: walk leisurely for exercise or pleasure outdoors; walk fast or briskly for exercise outdoors; and walk or hike uphill outdoors.

[b]Sum of: walk to do errands; and walk to visit friends, family or neighbors

Table 2

Correlations between objective and perceived built environment variables in 2,732 older women in Nurses' Health Study cohort

	1	2	3	4	5	6	7	8	9
1. Population density[a]	-								
2. Stores/services density[a]	0.66	-							
3. Intersection density[a]	0.51	0.36	-						
4. Walking infrastructure[b]	0.39	0.31	0.46	-					
5. Street connectivity[b]	0.27	0.22	0.42	0.46	-				
6. Aesthetics[b]	−0.02	−0.04	−0.05	0.09	0.11	-			
7. Traffic safety[b]	0.02	−0.02	0.14	0.20	0.24	0.26	-		
8. Personal safety[b]	−0.29	−0.20	−0.24	−0.19	−0.11	0.24	0.28	-	
9. Land use mix[b]	0.42	0.43	0.42	0.49	0.41	0.13	0.12	−0.15	-
M (SD)	1404.7 (1668.2)	1.3 (1.6)	4.0 (1.3)	2.4 (1.0)	2.7 (0.9)	3.3 (0.6)	2.8 (0.8)	3.6 (0.5)	2.1 (1.0)

[a]Objective built environment variables (1200 m line-based network buffer around 2008 residential address).

[b]Perceived built environment variables (from a modified version of the ANEWS)

Table 3

Indirect effects of objective[a] built environment variables on leisure walking[b] from full models that control for all other variables among 2,732 Nurses' Health Study participants from California, Massachusetts, and Pennsylvania

	Independent variables predicting "any" leisure walking Odds ratio (95% BCa CI)[c]			Independent variables predicting ≥150 minutes leisure walking Odds ratio (95% BCa CI)[c]		
Mediating variables[d]	**Objective population density**	**Objective intersection density**	**Objective stores and services density**	**Objective population density**	**Objective intersection density**	**Objective stores and services density**
Perceived walking infrastructure	1.00 (99, 1.02)	1.01 (.98, 1.04)	1.00 (1.00, 1.01)	1.00 (.99, 1.02)	1.01 (0.98, 1.04)	1.00 (1.00, 1.01)
Perceived street connectivity	1.00 (.99, 1.00)	.98 (.95, 1.01)	1.00 (.99, 1.00)	1.00 (.99, 1.00)	.98 (.95, 1.01)	1.00 (.99, 1.00)
Perceived aesthetics	**1.**00 (.99, 1.01)	.99 (.98, 1.00)	.99 (.98, 1.00)	1.00 (.99, 1.01)	.99 (.98, 1.00)	99 (.98, 1.00)
Perceived traffic safety	1.00 (.99, 1.00)	1.01 (1.00, 1.03)	1.00 (.99, 1.00)	1.00 (.99, 1.00)	1.01 (.99, 1.02)	1.00 (.99, 1.00)
Perceived personal safety	1.01 (.99, 1.02)	1.00 (1.00, 1.01)	1.00 (1.00, 1.00)	1.00 (.99, 1.02)	1.00 (.99, 1.01)	1.00 (1.00, 1.00)
Perceived land use mix	**1.01 (1.00, 1.03)**	**1.05 (1.02, 1.08)**	**1.04 (1.02, 1.06)**	**1.01 (1.00, 1.02)**	**1.03 (1.01, 1.06)**	**1.02 (1.01, 1.04)**

Note: Table 3 includes indirect effects for leisure walking models shown in Figure 1. Statistically significant indirect effects are shown in bold font.

[a]Objective built environment variables (1200 m line-based network buffer around 2008 residential address)

[b]Sum of: walk leisurely for exercise or pleasure outdoors; walk fast or briskly for exercise outdoors; and walk or hike uphill outdoors

[c]Multiple regression models with 95% bias corrected and accelerated CIs generated using bootstrap resampling methods (k=10,000), adjusted for age, race, Hispanic ethnicity, education, walking limitations, BMI categories

[d]Perceived built environment variables (from a modified version of the ANEWS)

Table 4

Indirect effects of objective[a] built environment variables on utilitarian walking[b] from full models that control for all other variables among 2,732 Nurses' Health Study participants from California, Massachusetts, and Pennsylvania

	Independent variables predicting "any" utilitarian walking Odds ratio (95% BCa CI)[c]			Independent variables predicting ≥150 minutes utilitarian walking Odds ratio (95% BCa CI)[c]		
Mediating variables[d]	**Objective population density**	**Objective intersection density**	**Objective stores and services density**	**Objective population density**	**Objective intersection density**	**Objective stores and services density**
Perceived walking infrastructure	1.01 (1.00, 1.02)	1.02 (.99, 1.05)	1.00 (1.00, 1.01)	1.01 (.99, 1.03)	1.02 (.98, 1.06)	1.00 (1.00, 1.01)
Perceived street connectivity	1.00 (1.00, 1.01)	1.01 (.98, 1.04)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	1.02 (.98, 1.08)	1.00 (1.00, 1.01)
Perceived aesthetics	1.00 (1.00, 1.01)	1.00 (.99, 1.00)	1.00 (.99, 1.00)	1.00 (1.00, 1.01)	1.00 (.99, 1.00)	1.00 (.99, 1.00)
Perceived traffic safety	1.00 (1.00, 1.00)	1.00 (.98, 1.01)	1.00 (1.00, 1.01)	1.00 (1.00, 1.01)	.98 (.96, 1.00)	1.01 (1.00, 1.02)
Perceived personal safety	1.00 (.98, 1.01)	1.00 (.99, 1.01)	1.00 (.98, 1.00)	.99 (.96, 1.00)	.99 (.97, 1.00)	1.00 (.99, 1.00)
Perceived land use mix	**1.02 (1.00, 1.04)**	**1.07 (1.04, 1.09)**	**1.05 (1.03, 1.07)**	**1.02 (1.00, 1.05)**	**1.08 (1.04, 1.12)**	**1.06 (1.03, 1.09)**

Note: Table 4 includes indirect effects for utilitarian walking models shown in Figure 1. Statistically significant indirect effects are shown in bold font.

[a] Objective built environment variables (1200 m line-based network buffer around 2008 residential address)

[b] Sum of: walk to do errands; and walk to visit friends, family or neighbors

[c] Multiple regression models with 95% bias corrected and accelerated CIs generated using bootstrap resampling methods (k=10,000), adjusted for age, race, Hispanic ethnicity, education, walking limitations, BMI categories

[d] Perceived built environment variables (from a modified version of the ANEWS)