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Using Built Environmental Observation Tools: Comparing Two Methods of Creating a Measure of the Built Environment

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Abstract

Purpose—Identify an efficient method of creating a comprehensive and concise measure of the built environment integrating data from geographic information systems (GIS) and the Senior Walking Environmental Assessment Tool (SWEAT).

Design—Cross-sectional study using a population sample.

Setting—Eight municipally defined neighborhoods in Portland, Oregon.

Subjects—Adult residents (N = 120) of audited segments (N = 363).

Measures—We described built environmental features using SWEAT audits and GIS data. We obtained information on walking behaviors and potential confounders through in-person interviews.

Analysis—We created two sets of environmental measures, one based on the conceptual framework used to develop SWEAT and another using principal component analysis (PCA). Each measure's association with walking for transportation and exercise was then assessed and compared using logistic regression.

Results—A priori measures (destinations, safety, aesthetics, and functionality) and PCA measures (accessibility, comfort/safety, maintenance, and pleasantness) were analogous in conceptual meaning and had similar associations with walking. Walking for transportation was associated with destination accessibility and functional elements, whereas walking for exercise was associated with maintenance of the walking area and protection from traffic. However, only PCA measures consistently reached statistical significance.

Conclusion—The measures created with PCA were more parsimonious than those created a priori. Performing PCA is an efficient method of combining and scoring SWEAT and GIS data.

Keywords

Environment; Residence Characteristics; Walking; Principal Component Analysis; Research Design; Prevention Research

PURPOSE

Ensuring that built environments are conducive to walking is a central component of encouraging physical activity at the community level. The term *built environment* encompasses urban design, land use, and transportation systems; it defines and describes the communities in which individuals live and therefore influences lifestyles and choices made by inhabitants of those communities.¹⁻³

Research into associations between characteristics of the built environment and health has relied primarily on self-reported descriptions of environmental elements,⁴⁻⁶ or more recently, on data collected from geographic information systems (GIS) or other existing transportation and urban planning data.⁷⁻¹⁰ Although GIS measures are based on objective data lacking in subjective self-reports, they describe only general environmental characteristics and are typically available only on broad scales and from large geographic areas defined by administrative boundaries.¹¹

To improve the specificity of neighborhood characterization, observational audit instruments¹²⁻¹⁴ have been developed to quantify objective measures of specific environmental features within a precisely defined area. Microscale data generated by these tools can provide insightful and specific information for designing targeted interventions to encourage physical activity in a community. However, there has been little research on how to efficiently analyze the large amount of data generated by these audit instruments, and as a result, their utility has been limited thus far.

This study will address this gap in usability by identifying a scoring method that balances describing precise built environment features and reducing the number of measures for analysis using available data collected with the Senior Walking Environmental Assessment Tool (SWEAT), a microscale audit instrument developed from a clear conceptual framework. Specifically, this study will (1) develop two sets of environmental measures integrating GIS and audit data, one based on the conceptual framework used to design SWEAT and a second based on principal component analysis (PCA) and (2) evaluate the efficiency of each method by comparing the two sets of measures in their association with walking behavior. In determining which method is more efficient at creating comprehensive and concise composite measures, we will provide researchers investigating numerous aspects of the built environment with a method of managing observational data generated by audit tools such as SWEAT.

METHODS

Design

This cross-sectional study was conducted in 2007 using data collected in 2002 to 2003 as part of a study of characteristics of the built environment and health among urban seniors. SWEAT audits and resident interviews were conducted on a random sample of street segments (N = 363) in eight municipally defined neighborhoods recognized by the Portland Office of Neighborhood Involvement. These neighborhoods were selected from control neighborhoods in the Senior Health and Physical Exercise study, a walking-program randomized trial in 56 Portland neighborhoods.¹² Characteristics of selected neighborhoods

are provided in Table 1. The Oregon Health & Science University's Institutional Review Board approved this study.

Sample

The study population was defined as residents of audited street segments. Households whose tax lots were on or adjacent to the audited street segments were canvassed by trained interviewers in the summer of 2003. Interviewer training occurred over 2 days and included reviewing the extensive training manual and a practical competency exam. In addition to retaining the training manual for reference, interviewers and study staff met bi-weekly to review issues or questions that arose. Each face-to-face interview took approximately 15 minutes to complete. Canvassing occurred on weekdays between 3:00 and 7:00 PM; households at which no one answered the door were canvassed a second time. The first resident 18 years or older who was able to provide informed consent was interviewed. A total of 128 adults were interviewed. The survey response rate was 32% among households with someone answering the door. Participants with three or more audited street segments within one-quarter of a mile (402 m) of their household were included in this analysis.

Information on potential confounders (gender, race/ethnicity, years of residence in the area, frequency of physical activity, and overall health status) were self-reported during the structured interviews. Because of a low frequency of nonwhite respondents, race/ethnicity was collapsed to "white, non-Hispanic" and "other." Years of residence in the area was dichotomized as "less than 10 years" and "10 years or longer." Physical activity was assessed by asking, "On average, how often in a typical week do you exercise for 20 minutes or more at a level that increases your breathing rate enough to raise a sweat?" (responses: "never" to "a great deal") and collapsed to "never" and "at least once per week." General health was measured on a five-point Likert scale ("poor" to "excellent") and collapsed to "poor/fair" and "good or better." Initially, data on gender were not recorded to protect interviewees' identities; however, a change in protocol during the latter half of the study period allowed gender data to be collected from participants interviewed during the second half of the data collection process.

Measures

Built Environment Features—Built environment features were measured through GIS and SWEAT audits by five teams of trained observers between October 2002 and August 2003. The 35-question SWEAT instrument measures a variety of street, sidewalk, and building characteristics hypothesized to influence walking behaviors, particularly among older adults.¹² SWEAT was developed using a conceptual framework based on themes appearing in an extensive literature review and two published frameworks.^{6,14} Reliability of the SWEAT instrument was assessed and described previously.¹² Briefly, inter-rater reliability of SWEAT was assessed from audits of 36 randomly sampled street segments in Portland, Oregon, using κ scores and intraclass correlation coefficients. Raters had acceptable agreement ($\kappa > .6$ or $r > .6$) on 67% of items; the aesthetics and destinations domains were less reliable than functionality and safety domains. GIS can augment information obtained from street-level SWEAT audits. For instance, a park could be missed if it is not adjacent to a sampled segment. Similarly, a random sample of segments may not accurately measure the availability of destinations because businesses tend to cluster on one street. To most completely describe neighborhood built environments with available resources, SWEAT audits and GIS data were combined.

In this study, SWEAT data for all segments within a participant's local neighborhood were aggregated to create neighborhood-level built environment variables. One-quarter of a mile was selected as the definition of a "local neighborhood" because this distance is frequently

used in the literature¹⁵⁻¹⁸ and is common for walking trips. Audited segments were included in a participant's local neighborhood if any part of the segment fell within one-quarter of a mile of any point on the household's segment. Alleyways ($n = 7$) were excluded from analysis. Details of neighborhood-level variables are provided in the appendix. Items with little or no variance across participants or with a high percentage of missing values were eliminated from further analysis.

GIS data on amenities within one-quarter of a mile of each audited street segment were obtained using Arcview 3.3 (ESRI, Redlands, California) linked to the Regional Land Information System, a GIS database maintained by Metro, the regional planning agency for the Portland metropolitan area. Counts of amenities were summed into four mutually exclusive categories: (1) shopping (neighborhood grocery, convenience stores, supermarkets, malls), (2) medical (hospitals, medical offices), (3) services (libraries, pharmacies, banks, beauty shops, schools, senior services), and (4) activities (community centers, senior centers, pools, parks/trails, community gardens). Counts of bus stops and restaurants, as well as street segment length, were also obtained.

Walking Behavior—Walking behaviors were assessed through structured interviews. Walking for transportation was measured by asking participants, "What form of transportation do you use to get where you need to go?" Participants could report up to three modes of transportation (car, motorcycle, or moped; public transport; bicycle; walking; other; never goes out). Interviewers allowed for spontaneous responses but read options if the participant did not offer a response. For this analysis, participants were dichotomized into those who reported walking and those who did not. Walking for exercise was measured by the question, "How often in a typical week do you walk for exercise in your neighborhood?" Participants selected from the responses: never (0 times per week), a little bit (1–2 times per week), a moderate amount (3–4 times per week), quite a bit (5–6 times per week), or a great deal (everyday). The response categories were collapsed to "never" and "at least once per week" to be comparable with walking for transportation.

Analysis

Two sets of built environment summary variables were created. The first set of summary variables was based on SWEAT'S conceptual model, which classifies built environment features into four categories hypothesized *a priori* to be associated with walking: functionality, safety, aesthetics, and destinations.¹² The second set of data-driven summary variables was created using PCA.

An exploratory PCA with varimax rotation was used to group built environment variables into theoretical indices. All variables were included unless they were visually highly skewed and unable to be transformed (to comply with assumptions of PCA). The appropriate number of factors to retain was determined by reviewing the resulting rotated factor pattern matrix and scree plot. Variables were considered to load on a given factor if the factor loading was at least .40 and did not load on more than one retained factor.¹⁹

Summary variables based on the PCA and *a priori* categorizations were constructed by summing built environment variables standardized to a normal distribution (mean = 0, SD = 1). Standardized variables were assigned negative values in the *a priori* measures if the variable was hypothesized to be inversely associated with walking, whereas variables were assigned negative values in the data-driven measures if the original (unstandardized) variable had a negative correlation greater than .15 with walking for transportation or exercise. PCA loading coefficients were not used in summation because they are often data driven and the aim of this study was to develop a robust composite measure.

Logistic regression was used to investigate the association between built environment summary variables and walking outcomes. Potential confounders that changed an environment measure's odds ratio (OR) by more than 10% or were significantly related to environment measures and walking outcomes were retained in multivariable models. The significance of between-group differences in potential confounders was assessed using χ^2 or Fisher's exact test when cell values were less than five. Possible interaction effects were examined by stratifying models by covariates. Analyses were conducted using SAS, version 9.1 (SAS Institute Inc, Cary, North Carolina).

RESULTS

After interviewed participants were matched with audited segments, data from 120 adults who had three to 18 audited segments within their local neighborhoods were available for analysis. Men and minorities were undersampled, similar to other surveyed samples.²⁰ Most participants were white (83.4%); of the 59 participants whose gender was recorded, 64.4% were female. On average, participants had lived in their neighborhoods for 13.7 years, and half reported engaging in some physical activity three or more times per week (50.8%). Table 2 provides the distribution of participant characteristics stratified by walking outcomes. Walking was a primary mode of transportation for 29.2% of participants, and 80.8% of participants walked for exercise at least once per week.

Twenty-six environmental variables were included in the PCA (Table 3) after exclusion of 11 visually highly skewed variables. Four components, accessibility, maintenance, comfort/safety, and pleasantness, were retained from the PCA, accounting for 57.2% of the total variance. Accessibility described the presence of transportation pathways and destinations. Presence of unbarred windows loaded in this component, likely because it was correlated with characteristics of commercial areas. The second component, maintenance, described the physical condition of environmental features. The third component, comfort/safety, described a pathway that may feel more comfortable and safe to a pedestrian because of a level sidewalk, separation from traffic, and low traffic volume. The fourth component, pleasantness, included features that may make a walking trip more serene or attractive, such as porches, buffer zones, and traffic-calming devices.

Variables included in each built environment summary measure are shown in Table 4. Curb height was hypothesized to have an inverse association with walking and was assigned a negative value in the *a priori* measure calculation. No variables loading in PCA factors had negative correlations greater than .15 with walking for transportation or exercise; thus, none were assigned negative values.

The adjusted associations between environmental measures and walking outcomes are provided in Table 5. Walking for transportation was significantly associated with the PCA measures accessibility (95% OR = 1.15; CI, 1.04–1.26) and pleasantness (OR = 1.33; CI, 1.09–1.62) and with the *a priori* functionality measure (OR = 1.19; CI, 1.08–1.32). Walking for exercise was significantly associated with PCA comfort/safety (OR = 1.51; CI, 1.05–2.18) and marginally associated with PCA maintenance (OR = 1.15; CI, 1.00–1.33) and *a priori* safety (OR = 1.19; CI, 1.00–1.42).

To understand the effect of excluding non-normal variables from the PCA, a sensitivity analysis was performed using a third set of measures created by manually adding the excluded variables into individual PCA summary measures, based on their interpreted meanings. Results of all subsequent analyses using these PCA-expanded measures were similar but slightly less significant than results of the original PCA measures, suggesting that the additional variables added noise to the measures rather than improving them.

DISCUSSION

Two methods of creating neighborhood-level measures from data obtained from GIS and SWEAT audits were compared in their associations with walking for transportation and exercise using a sample of 120 community-dwelling adults in Portland, Oregon. Summary measures were created for the functionality, safety, aesthetics, and destinations indices on which SWEAT was based. A PCA created four summary measures interpreted as accessibility, maintenance, comfort/safety, and pleasantness.

A priori and PCA measures were analogous in conceptual meaning. A measure in each set described destinations (*a priori* destinations and PCA accessibility), functional elements (*a priori*, functionality and PCA pleasantness), appearance (*a priori* aesthetics and PCA maintenance), and safety (*a priori* safety and PCA comfort/safety). In addition, both sets of environmental measures had similar associations with walking for transportation and exercise. Participants who walked for transportation were more likely than those who did not to live in neighborhoods with high scores for destination accessibility and functional elements, such as wide sidewalks and buffer zones. On the other hand, participants who walked for exercise were more likely to live in well-maintained neighborhoods with protection from traffic. Additionally, no built environmental measure was associated with both transportation and exercise walking. This difference illustrates that environmental features that enable or discourage pedestrians depend on the purpose of the trip, confirming observations in previous studies.^{5,18,21}

However, whereas built environmental measures created using the conceptual model and PCA are similar in meaning and association with walking for transportation and exercise, *a priori* measures consistently failed to meet statistical significance. Our findings suggest that the SWEAT conceptual framework should be refined. The *a priori* measures safety and destinations did not have a statistically significant association with walking, despite similarity in conceptual meaning and built environmental components to significant PCA measures. The failure of the *a priori* measures to meet statistical significance may be due to the inclusion of built environmental items unrelated to the other items in the measures, thereby reducing their efficiency. These findings suggest that PCA may be a more efficient method of scoring data generated by SWEAT.

Built environmental features associated with walking in this study are consistent with existing research. Destinations, accessibility, and functional elements—appearing in accessibility, pleasantness, destinations, and functionality measures—were significantly associated with walking for transportation. This supports previous research finding walking for transportation to be more common in neighborhoods with greater ease of access^{18,21,22} and increased density and variety of destinations.^{18,21,23,24} Condition of facilities and pathways, pathway comfort, and traffic protection—forming maintenance, safety/comfort, aesthetics, and safety measures—were associated with walking for exercise, although the associations were not consistently significant. Previous research has also identified aesthetics²¹ and safety²⁵ as potential enablers of walking for exercise or leisure, but as in our study, the findings are not consistent. Safety has been found to be inversely related to walking.²³ Additionally, other studies failed to identify any significant built environmental predictors of walking for recreation.^{22,23,26} In contrast to our findings, previous studies have suggested destinations, particularly shopping²⁴ and recreational facilities,²⁰ to be conducive to walking for recreation. This may not have been observed in this study because recreational destinations were combined with other destinations.

This study supports prior research that identified built environment correlates of walking for exercise or transportation and adds to the body of research by proposing a method of

creating conceptually meaningful measures of neighborhood walkability from objective, microscale data. Despite the development of reliable audit tools such as SWEAT, which is capable of providing researchers a measure of specific built environment features, such tools are underutilized in research of the association between the built environment and physical activity. Although many recently published articles measured the built environment using GIS and existing databases,^{8,9,17,20,22,24,26-29} relatively few used audit instruments.^{15,16,18,23,30} Gathering microdata with audit tools remains more resource intensive than using existing GIS data, but the methodology outlined here can encourage the use of audit tools to more precisely describe environments by providing researchers with summary measures that can be more easily incorporated into models than individual items. Furthermore, previous studies that reduced audit tool data into summary measures focused on *a priori* hypotheses,^{18,23} whereas this study demonstrates that a data driven approach may yield more efficient measures.

Limitations of this study include the inability to control for potential confounders not included in the interview. We could not adjust for some potential confounders controlled for in other studies,^{8,9,15-17,21,31} such as age, socioeconomic status, educational attainment, and body mass index. In addition, participants may not be representative of the study population because canvassing typically occurred during the day on weekdays, when many working adults are not home. The relatively small number of participants who walked for transportation or did not walk for exercise limits the ability to find significant associations, perhaps explaining the marginally significant associations observed. Neighborhood built environment was represented by a sample of segments, sometimes as few as three, which may not be adequate for an accurate description.

Although outcome measures were not independently validated, they do have face validity. The walking for transportation question was derived from the social capital module of the 2000 to 2001 General Household Survey of Great Britain,³² which underwent several rounds of testing prior to implementation. The walking for exercise question is similar to an item in the Neighborhood Physical Activity Questionnaire,³³ which demonstrated excellent reliability ($\kappa > .75$).

The response rate in this study was low, although comparable to similar studies^{8,9,11,21,23} and surveys in the same population.²⁸ Selection bias may have been introduced if the response rate was associated with both neighborhood built environment and walking behaviors. For instance, effect size may have been underestimated if nonresponders were more likely to be nonwalkers from low-walkability neighborhoods. However, this is unlikely because the average response rate in the most walkable neighborhoods (33.5%) was similar to the rate in the least walkable neighborhoods (30.6%). The low response rate did result in reduced power owing to a smaller number of participating residents.

This study was relatively small in size; however, the study had *a priori* 80% power to detect a 13 percentage point difference in walking prevalence with a one-SD change in the accessibility measure of interest, assuming a low-walkability prevalence of 40% to 60% suggested by previous studies.^{23,24,26,29,34,35} In addition, an appropriate sample size for PCA may be estimated by five times the number of variables being analyzed.¹⁹ As the sample at the lower boundary suggested, the fact that the PCA constructs mapped well into *a priori* constructs and the direction of the results is similar between the two approaches provides confidence in the results of this current study. Validity of the methodologic approach proposed in this study can be further validated by using it in additional larger studies in more diverse geographic areas.

This study may not be generalizable outside of Portland, Oregon. Observation was done within established, traditional neighborhoods in a city in the Northwest United States. Studies in other communities with variations in environment and behavior are needed to assess whether the constructs identified here are reproduced and therefore valid outside of this study population.

This study provides researchers with an efficient method of creating a comprehensive and concise measure of the built environment, integrating two powerful and complementary objective measurement tools: audit instruments and GIS.

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Appendix

Appendix

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Local Neighborhood-Level Variable	Description	Mean (SD)	Source
Residential density	Percent of buildings that are multiple-family dwellings	0.14 (0.13)	SWEAT
Nonresidential use	Percent of buildings that are nonresidential (institutional, retail, commercial, public, religious)	0.11 (0.14)	SWEAT
Mixed use	Percent of buildings that are mixed use	0.01 (0.02)	SWEAT
Short buildings	Percent of buildings less than 3 stories tall	0.92 (0.11)	SWEAT
Unbarred windows	Percent of buildings without bars on windows	0.84 (0.10)	SWEAT
Porches	Percent of residential buildings with porches	0.54 (0.15)	SWEAT
Well-maintained yards	Percent of segments with well-maintained yards	0.82 (0.12)	SWEAT
Well-maintained buildings	Percent of segments with well/fair-maintained buildings	0.89 (0.12)	SWEAT
Tree density	Average number of trees ≥ 15 feet tall per 100 segment feet	0.01 (0.00)	SWEAT
Resting place density	Average number of resting places per 100 segment feet	0.00 (0.00)	SWEAT
Litter score	Average litter rating across segments (1 = little litter, 0 = heavy litter)	0.69 (0.21)	SWEAT
Restrooms	Total number of restrooms	1.00 (1.51)	SWEAT
Streetlight density	Average number of streetlights per 100 segment feet	0.01 (0.00)	SWEAT
Curbside parking	Percent of segment sides with curbside parking (for retail)	0.10 (0.11)	SWEAT
Lot parking	Percent of segment sides with parking lots (for retail) in front of buildings	0.08 (0.09)	SWEAT
Continuous sidewalks	Percent of segment sides with continuous sidewalks	0.96 (0.05)	SWEAT
Gentle slope	Percent of segment sides with flat/gentle sidewalk slope	0.89 (0.14)	SWEAT
Hard-surface sidewalks [†]	Percent of segment sides with concrete and/or asphalt sidewalks	1.00 (0.00)	SWEAT
Well-maintained sidewalks	Percent of segment sides with sidewalks in good/fair condition	0.59 (0.20)	SWEAT
Wide sidewalks	Average sidewalk width (inches)	63.89 (4.04)	SWEAT
Unobstructed sidewalks	Percent of segment sides without sidewalk obstructions	0.45 (0.18)	SWEAT
Buffer zones	Percent of segment sides with buffer zones	0.91 (0.10)	SWEAT

Local Neighborhood-Level Variable	Description	Mean (SD)	Source
Buffer zone width	Average buffer zone width (inches)	61.65 (15.66)	SWEAT
Through streets	Percent of segments that are through roads (vs. dead-ends)	0.97 (0.05)	SWEAT
Narrow roads	Percent of segments with 1 or 2 lanes of traffic	0.93 (0.10)	SWEAT
Bike lanes	Percent of segments with bike lanes	0.07 (0.11)	SWEAT
Traffic-calming devices	Percent of segments with traffic-calming devices	0.31 (0.18)	SWEAT
Posted speed limit	Percent of segments with speed limit ≤25 miles per hour	0.97 (0.05)	SWEAT
Crossing signals [‡]	Percent of signaled intersections with pedestrian signals	0.60 (0.44)	SWEAT
Crossing signal time [‡]	Average pace (feet per second) to cross street during pedestrian signal	1.15 (0.66)	SWEAT
Curb cuts	Percent of segments with curb cuts at crossings	0.50 (0.19)	SWEAT
Curb height	Average curb height (inches)	4.97 (0.43)	SWEAT
Traffic load	Average number of cars per minute	3.16 (2.26)	SWEAT
Block length	Average segment length (feet)	318.24 (53.69)	GIS/RLIS
Bus stops	Number of bus stops within one-quarter of a mile	13.08 (6.04)	GIS/RLIS
Restaurants	Number of restaurants within one-quarter of a mile	3.69 (4.07)	GIS/RLIS
Shops	Number of retail/shopping businesses (neighborhood grocery, convenience stores, supermarkets, malls) within one-quarter of a mile	1.91 (1.64)	GIS/RLIS
Medical facilities	Number of medical facilities (hospitals, medical offices) within one-quarter of a mile	0.70 (0.91)	GIS/RLIS
Services	Number of services (libraries, pharmacies, banks, beauty shops, schools, senior services) within one-quarter of a mile	3.12 (2.54)	GIS/RLIS
Activities	Number of activities (community centers, senior centers, pools, parks/trails, community gardens) within one-quarter of a mile	0.44 (0.79)	GIS/RLIS

* SWEAT indicates Senior Walking Environmental Assessment Tool; GIS, geographic information systems; and RLIS, Regional Land Information System.

[‡] Excluded from analysis because of no variance across participants.

[‡] Excluded from analysis because of high percentage of missing values.

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Table 1
Characteristics From the 2000 Census of Audited Municipally Defined Neighborhoods (N = 8)*

	Median	Range
Area, acres	698	204–7055
Total population	8079	3033–15,987
Households per acre	5.1	0.6–8.8
Female	50.8%	47.8%–54.2%
White	71.1%	33.5%–80.0%
<18 years	19.9%	10.1%–28.9%
>65 years	9.7%	4.9%–18.9%
College degree or higher	21.9%	11.7%–46.1%
Housing units owner occupied	50.5%	15.5%–61.9%
Median value of owner-occupied units	\$136,609	\$119,275–\$263,711
Median annual household income	\$36,480	\$26,097–\$44,959
Below poverty line	15.8%	10.4%–22.0%
Walk to work	4.5%	2.2%–16.2%

* Source: Office of Neighborhood Involvement, City of Portland, Oregon.

Table 2
Participant Characteristics by Use of Transportation and Exercise Walking

	Walking for Transportation		Walking for Exercise	
	Yes n = 35	No n = 85	Ever n = 97	Never n = 23
Race				
White, non-Hispanic	29	64	74	19
Other	2	16	16	2
Missing	4	5	7	2
Gender				
Male	5	16	14	7
Female	15	23	32	6
Missing	15	46	51	10
Residence time				
≥ 10 years	16	38	38	16*
<10 years	19	47	59	7
Physical activity level				
At least once per week	30	64	84	10*
Never	5	21	13	13
Health status				
Good or better	32	69	84	17
Poor/fair	3	15	12	6
Missing	0	1	1	0

* $p < 0.05$.

Table 3
Principal Component Factor Loadings and Percentage of Variance Explained*

Principal Component	Loading	Variance Explained
1 Accessibility		22.0%
Unbarred windows	0.57	
Sidewalk width	0.52	
Bus stops	0.71	
Restaurants	0.83	
Shops	0.66	
Square root of services	0.83	
2 Maintenance		14.5%
Well-maintained yards	0.85	
Litter score	0.54	
Well-maintained sidewalks	0.75	
Unobstructed sidewalks	0.80	
3 Comfort/safety		11.8%
Gentle slope	0.78	
Log of buffer zone width	0.74	
Square root of traffic load	-0.79	
4 Pleasantness		8.9%
Porches	0.71	
Buffer zones	0.44	
Traffic calming devices	0.90	

* Variables entered in principal component analysis: Square root of residential density, square root of nonresidential use, porches, resting place density, continuous sidewalks, sidewalk width, well-maintained sidewalks, gentle slope, unobstructed sidewalks, buffer zones, unbarred windows, well-maintained yards, well-maintained buildings, litter score, tree density, streetlight density, square root of traffic load, traffic calming devices, logarithm of buffer zone width, curb cuts, curb height, restaurants, shops, square root of services, inverse of block length, bus stops.

Table 4

Composition of Built Environmental Measures*

PCA Measures			
Accessibility	Pleasantness	Maintenance	Safety/Comfort
Destinations, facilities, pathways, transportation	Aesthetics, serenity of pathway Porches	Condition of facilities and pathways	Pathway comfort, traffic condition, and protection
Unbarred windows	Buffer zones	Well-maintained yards	Gentle slope
Sidewalk width	Traffic-calming devices	Well-maintained buildings	Log of buffer zone width
Bus stops		Litter score	Square root of traffic load
Restaurants		Unobstructed sidewalks	
Shops			
Square root of services			
A Priori Measures			
Destinations	Functionality	Aesthetics	Safety
Connectivity and facilities	Buildings, sidewalks, and street life	Views and maintenance	Personal and traffic safety
Restaurants	Square root of residential density	Tree density	Streetlight density
Shops	Square root of nonresidential use	Short buildings	Square root of traffic load
Medical facilities	Mixed use	Unbarred windows	Narrow roads
Square root of services	Porches	Well-maintained yards	Traffic-calming devices
Activities	Resting place density	Well-maintained buildings	Posted speed limit
Through streets	Continuous sidewalks	Litter score	Bike lanes
Inverse of block length	Wide sidewalks		Log of buffer zone width
Restrooms	Well-maintained sidewalks		Curb cuts
Bus stops	Gentle slope		(-) Curb height
Curbside parking	Unobstructed sidewalks		
Lot parking	Buffer zones		

* (-) denotes variables assigned negative values in measure summation.

Table 5
Odds Ratios for Environmental Measures and Likelihood of Walking*

Factor	Walking for Transportation		Walking for Exercise	
	OR (95% CI)	p	OR (95% CI)	p
PCA measures				
Accessibility	1.145 (1.038–1.262)	0.007	0.962 (0.860–1.076) [†]	0.495
Pleasantness	1.327 (1.087–1.621)	0.006	1.083 (0.896–1.311)	0.410
Maintenance	1.064 (0.933–1.214)	0.353	1.150 (0.997–1.325)	0.055
Comfort/safety	0.932 (0.720–1.205)	0.590	1.511 (1.047–2.180) [‡]	0.027
<i>A priori</i> measures				
Destinations	1.052 (0.991–1.116)	0.097	0.979 (0.915–1.048)	0.543
Functionality	1.193 (1.078–1.319)	<0.001	1.070 (0.954–1.199)	0.249
Aesthetics	1.060 (0.899–1.251)	0.487	1.149 (0.963–1.372) [‡]	0.123
Safety	1.097 (0.953–1.262)	0.198	1.190 (0.996–1.421)	0.055

* CI indicates confidence interval; and OR, odds ratio.

[†] Adjusted for physical activity level.

[‡] Adjusted for residence time.