Neighborhood Design and Walking

A Quasi-Experimental Longitudinal Study

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Background: Few studies have employed longitudinal data to examine associations between the physical environment and walking.

Methods: Using cross-sectional (n=70) and longitudinal (n=32) data (collected 2003–2006), associations of neighborhood design and demographics with walking were examined. Participants were low-income, primarily African-American women in the southeastern U.S. Through a natural experiment, some women relocated to neo-traditional communities (experimental group) and others moved to conventional suburban neighborhoods (control group).

Results: Post-move cross-sectional comparisons indicated that women in neo-traditional neighborhoods did not, on average, walk more than women in suburban neighborhoods. Race and household size were significant predictors of physical activity. Additionally, using longitudinal data, this study controlled for the effects of pre-move walking and demographics. Analyses examined the effects of environmental factors (e.g., density, land-use mix, street-network patterns) on post-move walking. Women who moved to places with fewer culs-de-sac, on average, walked more. Unexpectedly, increases in land-use mix were associated with less walking.

Conclusions: Results suggest that neo-traditional neighborhood features alone (e.g., sidewalks, front porches, small set-back distances) may not be enough to affect walking; however, changes in street patterns may play a role.
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Introduction

While rates of inactivity in the U.S. are at epidemic levels across the population,[1,2] African-American women,[3,4] people of low SES,[5] and those living in the southeastern U.S. are particularly at risk for inactivity, obesity, and associated health problems.[1] Few studies have examined associations between physical environment characteristics and walking among the most at-risk groups.[6,7] To gain a clearer understanding of the impact of neighborhood design on walking, both cross-sectional and longitudinal data were used to address methodologic limitations common in prior research, focusing on a group vulnerable to sedentary lifestyles and the associated health risks.

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It has been suggested that physical activity levels might be influenced more effectively by physical environment interventions than by educational campaigns espousing the benefits of exercise.[8] "New urbanism" or "neo-traditional" neighborhood design incorporates design features common in neighborhoods constructed in the early 1900s such as front porches, sidewalks, and rear parking, as well as small lots, high density, and mixed land use. Proponents of this urban design trend claim that greater walking is among the likely benefits, and yet evidence is sparse.[9,10]

To date, most studies examining connections between neighborhood- design and walking have been limited by (1) the use of cross-sectional data and (2) self-selection into neighborhoods. Cross-sectional studies suggest relationships among variables and lead to causal hypotheses, but they do not establish causal linkages.[11,12] In contrast, longitudinal studies allow for within-subject comparisons whereby individuals serve as their own controls. This reduces threats to internal validity such as individual differences in the propensity to be physically active.

Because people typically choose where they live (i.e., self-selection), it is not possible to determine causal direction. Do people who like to walk **choose** to live in a walkable neighborhood, **or** do neighborhoods with pedestrian-oriented features actually promote walking?

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Because it is seldom possible to conduct a true experiment—randomly assigning people to residences—self-selection is a pervasive challenge.

By taking advantage of a rare natural experiment, this study tackled these methodologic challenges. It examined walking among women, who, through their partnership with a housing program, moved to either (1) a neo-traditional (or new urbanist) community with small lots, modest setback distances, front porches, sidewalks, a central recreation area, and rear automobile parking[13–15] or (2) a conventional suburban neighborhood with large lots, substantial setbacks, long driveways, no sidewalks, and no shared recreation space. Both pre- and post-move data were obtained. Because only one neighborhood was built within each region, participants did not have a choice between neighborhood types. In this way, the research design incorporated quasi-random assignment to neighborhood type and addressed the self-selection challenge.

The following questions were the study's focus:

1. Are there differences in weekly walking between women living in neo-traditional neighborhoods and those living in conventional suburbs?
2. What environmental characteristics predict post-move walking (according to longitudinal data that control for pre-move walking)?

Methods

Research Design

This article presents a two-part study of walking. First, a cross-sectional, between-groups comparison was used to examine the difference in post-move walking between women living in neo-traditional neighborhoods and those in the suburban neighborhoods. Second, walking data collected prior to relocation to the new neighborhoods were introduced, and thereby a quasi-experimental, longitudinal (pre-move/post-move) research design was employed. The effects of changes in environmental characteristics such as density, land-use mix, and street-network pattern "connectivity" (i.e., the "griddedness" of streets) on post-move walking were examined, controlling for pre-move walking and various demographic variables.

Participant Recruitment and Procedure

The names of women who had partnered with the self-help housing organization Habitat for Humanity were provided by the local organization in four towns in the southeastern U.S. The towns, located in Georgia, Alabama, and Florida, were selected because in each, Habitat for Humanity was constructing a new neighborhood. Trained research assistants collected demographic data; weight and height were measured using a Seca Model 882 digital read-out scale accurate to 0.1 kg and an Invicta portable stadiometer to calculate BMI (kg/m^2). The female head of household was interviewed and trained in the use of a pedometer. Data were collected in 2003–2006. Some women had already moved when data collection began, therefore, the post-move sample (n=70) is larger than the longitudinal sample (n=32). The Cornell University Institutional Review Board approved the study. Written informed consent was acquired from each participant, and each participant was given $40 as a thank-you. The baseline response percentage (pre-move) was 64%; at follow-up, 74% participated. The response percentage of post-move-only participants (who had moved prior to study commencement) was 69%.

Constructs and Measures

Independent variables: neighborhood characteristics, street-network patterns, and land-use conditions. The physical environment was measured in several ways. Independent variables included measures of neighborhood type, street-network patterns, and land-use conditions.

Post-move neighborhoods were characterized as either neo-traditional or suburban as previously described (Table 1). In addition to these architectural design features, characteristics of the neighborhood at a scale relevant to the respondents' walking behavior were also considered. Variables to capture

Table 1. Post-move neighborhood characteristics (n=70)

	Neo-traditional		Suburban	
	Town 1	**Town 2**	**Town 3**	**Town 4**
Number of cases	19	7	16	28
Mean lot size (feet)	45×90	60×80	100×150	60×100
Setback distance (feet)	15	25	50	40
Sidewalks	Yes	Yes	No	No
Front porches	Yes	Yes	No	No
Public open space	Yes	Yes	No	No
Population density (person per acre)	1.60	2.26	1.01	0.93
Housing density (dwelling units per acre)	0.63	0.88	0.40	0.38
Employment density (# of jobs per acre)	1.00	0.16	0.04	0.26
Service job density (# of jobs per acre)	0.10	0.43	0.00	0.18
Employment/resident ratio	0.63	0.08	0.04	0.28
Service job/resident ratio	0.27	0.04	0.00	0.19
Mean number of culs-de-sac	0	1	2	3
Mean number of 4-way intersections	4	2	0	0
Mean total street length within ¼ mile (feet)	8437.76	4811.44	5315.5	3884.8

Table 2. Summary of neighborhood variables considered in analyses

Neighborhood design measures	Method of variable construction
STREET NETWORK CHARACTERISTICS	
Total linear length of streets	Sum of street segment length within ¼ mile
No. of street intersections	No. of X- and T-intersections within ¼ mile
No. of culs-de-sac	No. of culs-de-sac (dead ends) within ¼ mile
LAND-USE CHARACTERISTICS	
Density	
Population density	Total population/total land area
Employment density	Total no. of jobs/total land area
Housing density	Total no. of housing units/ total land area
Service-job density	No. of jobs in service sectors/ total land area
Land-use mix	
Service-jobs/population ratio	No. of jobs in service sectors/ total population
Job/resident ratio	Total no. of jobs/total population

No., number.

street-network patterns and the land-use conditions surrounding residences were constructed (Table 2).

Four geographic information system (GIS)–derived variables were used to describe street griddedness. These variables were calculated for both pre-move and post-move residences, based on a network buffer zone (NBZ), defined as the area within one-quarter mile of the residence along the existing streets.[16,17] The four variables are (1) total area of the NBZ (acres); (2) total length of streets within the NBZ (feet); (3) number of intersections within the NBZ; and (4) number of culs-de-sac within the NBZ.

Two land-use characteristics—land-use density and mixed land use—were measured using GIS data. Variables were constructed using data from the 2000 Census[18] and the 2000 Census Transportation Planning Package (CTPP)[19] and were computed at the level of census tract or Traffic Analysis Zone (TAZ). Because the study's comparisons were within subjects, the unit type was consistent within each case from pre-move to post-move, although it varied from town to town.

Four variables were used to gauge land-use density or compactness: (1) population density (household persons per acre); (2) housing density (dwellings per acre); (3) employment density (workers per acre); and (4) service-job density (service workers per acre). "Service jobs" include positions in the retail field; the arts; entertainment; recreation; accommodation and food services; and educational, health, and social services. The designation is used to identify the concentration of land uses likely to be attractive destinations for walking trips.[17]

Two variables measured the land-use mixture: (1) the jobs-(workers)-per-resident ratio and (2) the service-worker-to-resident ratio. These variables indicate the prevalence of nonresidential land uses in a neighborhood—neighborhoods with a high ratio of employment to residents are more likely to be business-oriented places.

Demographic variables. Demographic variables included age, marital status, household size, number of adults in the household, number of children in the household, BMI, and ethnicity.

Outcome variable: walking. The dependent variable, walking, was assessed using the same procedure prior to and following relocation using Accusplit Eagle 170 Digi-Walker2 pedometers. Digi-Walker pedometers have been found to have exceptional reliability and validity. In a field-based evaluation, the Digi-Walker measured steps and distance to within 1% of actual values.[20] Reliability has also been found to be acceptable with sedentary adults.[21] Participants used the pedometer and completed a brief activity log for 4 days—two weekdays and a full weekend. Steps per week were calculated based on these data. For nine participants (12.9% of the 70 total participants), steps/week was calculated based on 3 days of data, because the fourth day was missing.

Participants were instructed to wear the pedometer on an elasticized belt around the waist from the time they got up in the morning until they went to bed, except for when they showered, bathed, or swam. The pedometer and activity log were returned by the participants.

Statistical Analyses

A two-step analytic strategy was employed to examine the relationship between environmental features and walking, first cross-sectionally and then longitudinally.

Cross-sectional analyses. General linear modeling (GLM) was used to examine the impact of neighborhood type on post-move walking. Due to differences in walking among towns and the overlap of town and neighborhood type (two towns built neo-traditional neighborhoods and two built conventional suburban neighborhoods), it was necessary to decompose the effects of neighborhood type from the influence of town. To accomplish this, an interaction term (neighborhood type× town) was included in the analysis. The interaction term removes the between-town differences within the same neighborhood type, leaving a clearer estimate of the influence of neighborhood type alone. The effects of race and household size were also controlled.

Longitudinal analyses. The longitudinal analyses examined which variables explain post-move walking. Using mixed modeling, researchers incorporated pre-move measures of walking and environmental characteristics to examine the effects of change (pre-move to post-move) in environmental characteristics, such as land-use mix, land-use density, and street-network pattern on post-move walking, while controlling for pre-move walking. A series of three models examined pre-move walking, demographic variables, and change in environmental characteristics as predictors.

The relative predictive power of the independent variables was assessed by examining changes in the proportion of variance explained in the dependent variable with the addition of variables. By computing the reduction in residual variance from one model to another, the variation in post-move walking explained by the addition of variables was estimated,[22] as described by Singer[22] and by Bryk and Rau-

Table 3. Characteristics of study samples

	Cross-sectional sample (n=70)			
	Suburban	Neo-traditional	t-test	Longitudinal sample (n=32)
n	44	26		32
Age (M)	38.72	35.77	1.235	38
SD	8.61	10.19		8.47
Annual income (M)	16,843.44	14,725.56	1.212	16,425.75
SD	5,652	6,276		5,586
African American (%)	88.6	57.7	—	72
BMI (M)	33.10	29.12	2.281*	32.09
Overweight or obese (%)	88	65	—	82
High school graduate (%)	80	75	—	81
Household Size (M)	3.27	3.62	−0.874	3.69
SD	1.53	1.68		1.53

*p<0.05.

denbush.[23] The reduction in the variance component is referred to as variance explained (VE).

Results

Cross-sectional findings: walking in neo-traditional versus suburban neighborhoods. The cross-sectional analyses focused on whether the overall design of the neighborhoods is associated with the walking of residents. A cross-sectional, between-groups comparison of participants' walking in two different types of neighborhoods (neo-traditional and suburban) was conducted while controlling for the influence of participants' demographic characteristics.

The 70 women who participated in the cross-sectional study had relocated to new homes in either neo-traditional or suburban neighborhoods. The women were aged 23–66, with a mean age of 37.6. The racial composition of the group was 77.1% African-American, 17.1% white, and 5.7% other (i.e., Asian, Latina, and Native American). Seventy-nine percent of the participants were single, and 21% were married. The mean annual income was $15,967. The average household size was 3.4. The average number of children per household was 1.86, with a mode of 1 child. Seventy-eight percent of the sample had at least a high school education. The mean BMI was 31.58. Twenty-one percent had BMIs categorized as healthy, 25% as overweight, and 54% were categorized as obese or severely obese with BMI>30. The demographic characteristics of participants are described in Table 3.

The cross-sectional comparison indicated that while controlling for other significant predictors, including the potentially confounding influence of town, levels of walking in neo-traditional neighborhoods were slightly higher (62,207 steps/week) than in the suburban neighborhoods (58,617 steps/week). However, as shown in Table 4, this neighborhood difference is not significant (p=0.600). Demographic characteristics were strong predictors of walking. Holding other variables constant, on average African-American women walked 20,184 fewer steps per week (50,320 steps/week) than non–African-American women (70,504 steps/week) (p=0.013). In addition, women walked approximately 5600 more steps per week for each additional household member (p=0.008). Together, race, house-

Table 4. Cross-sectional analysis based on GLM (n=70)[a,b]

	Test of between-subjects effects			Parameter estimates		
					95% CI	
Variable	F	p	Partial Eta^2	B	Lower	Upper
Neighborhood type (1=neo-traditional)	(1,69)=0.278	0.600	0.128	7181	−20028	34391
Race (1=African American)	(1,69)=6.56	0.013	0.093	−20184	−4444	−35923
Household size	(1,69)=7.45	0.008	0.104	5599	1500	9699
Neighborhood type×town	(2,68)=15.31	0.000	c	c	c	c

[a]Income, education, BMI, and age were examined separately and were not significant.
[b]Dependent variable: walking—steps per week (post-move) R^2=34.
[c]Neighborhood type×town interaction was included to control for the nesting of towns in neighborhood types. It is a nuisance term without meaningful interpretation; therefore, these statistics are not provided.
GLM, general linear modeling.

hold size, and neighborhood type explained 34% of the variance in steps per week. Age, income, BMI, and education were not significant predictors of walking.

Longitudinal analyses: predicting post-move walking, controlling for pre-move walking. In the longitudinal analyses, the study focused on whether changes in environmental variables explain differences in post-move walking while controlling for pre-move walking.

Thirty-two of the 70 women in the cross-sectional analysis were included in the longitudinal study. (The difference in sample sizes is due to the fact that some women had already moved when the study began, so collecting pre-move data from them was impossible.) The average participant was a 38-year-old, African-American, single mother of one child, with an annual household income of $16,425. Participants were aged 23–60; the number of children per participant ranged from 0 to 7. On average, household size was 3.68. Eighty-one percent had at least a high school education. Seventy-five percent of the participants were single, and 25% were married. The sample was 71.9% (n=23) African American and 21.9% (n=7) white; it included one Native American woman (3.1%) and one Latina (3.1%).

After taking into account the predictive power of pre-move walking and demographic variables (i.e., race, household size), researchers found that pre-move to post-move changes in land-use mix and street-network patterns were significant predictors of participants' post-move walking. Each measure for street-network patterns, land-use conditions, and land-use mix was examined separately. With respect to land-use mix, increases in the service-jobs-to-residents ratio from pre- to post-move were associated with fewer steps per week (31,820 fewer steps per week, or 4545 fewer steps per day). In terms of street-network patterns, moving to an area with fewer culs-de-sac was associated with about 5303 more steps per week (757 more steps per day).

As shown in Table 5, the study found that pre-move walking explained 27.5% of the variance in individuals' post-move walking. Demographic variables (race and household size) explained an additional 16.0% of the variance. Changes in environmental characteristics (land-use mix and street-network patterns) contributed an additional 16.2% to explanatory power. The final model predicted nearly 60% of the explainable variance in post-move walking.

Discussion

The results of the cross-sectional analysis examining differences in walking between the "package" of neo-traditional versus suburban design features indicated that residents of neo-traditional neighborhoods did not walk significantly more than those living in suburban neighborhoods. As with prior research,[10] these analyses provided an inconclusive verdict regarding the walking-promoting properties of neo-traditional design.

Demographic variables were significant predictors of walking. Together, race and household size explained one third of the variance in post-move walking. Consistent with previous studies, data showed that African-American women walked less than non–African-American women.[5,7] The finding that household size is positively associated with walking is consistent with that of Greenwald and Boarnet,[24] who concluded that the number of children per household was a significant predictor of nonwork walking trips. Perhaps women who head larger households are more active because they do more shopping, cooking, laundry, and errands than women with smaller families. Or, if housing conditions are crowded, women may leave to take a walk in order to socially withdraw from a stressful, crowded environment.[25,26]

Longitudinal results indicated that within this group of low-income Southern women, pre-move to post-move changes in both street-network patterns and land-use mix did predict walking activity when the study controlled for both demographic characteristics and prior walking and,

Table 5. Longitudinal analysis based on mixed model (n=32); dependent variable: walking—steps per week (post-move)

	Estimate of fixed effect				
Variables entered	**Estimate**	**Std error**	***p***	**VE[a]**	**ΔVE**
Model 1				27.5%	
Pre-move steps	0.491	0.136	0.001		
Model 2				43.5%	16.0%
Pre-move steps	0.435	0.122	0.002		
Household size	5,723.30	238.4	0.024		
Race (1=African American)	−17,972.44	9,224.7	0.062		
Model 3				59.7%	16.2%
Pre-move steps	0.571	0.112	0.001		
Household size	3,697.34	2,149.30	0.098		
Race (1=African American)	−23,444.98	7,986.10	0.007		
Δ # service jobs/resident (land-use mix)	−31,820.34	11,921.57	0.013		
Δ # of cul-de-sacs (street pattern)	−5,303.10	2,219.76	0.025		

[a]VE, percentage of between-individual variance explained.

in addition, removed the self-selection threat to internal validity. The finding that moving to a place with fewer culs-de-sac predicted more walking was consistent with prior evidence that more–grid-like street-network patterns (characteristic of traditional neighborhoods rather than suburban ones) are associated with increased walking.[24,27] This finding suggests that creating communities with more connected streets may foster walking and therefore might be a practical health-promotion strategy. Perhaps other measures of street-network pattern (i.e., number of intersections and number of feet of street in NBZ) were nonsignificant because, in this context, they were associated with less safe, more heavily trafficked streets. Because the GIS data did not include either traffic volume or the presence or absence of sidewalks, the character of the streets throughout the NBZ is unknown.

With respect to land-use mix, the finding that increases in the prevalence of nonresidential land use are associated with less walking was contrary to expectation and previous findings that mixed use is associated with more walking.[28–30] This ambiguous finding suggests that a clearer understanding of the broader context would be helpful. Perhaps the nature of the nonresidential land uses makes walking unpleasant.[31] For example, if the businesses are not pedestrian- or family-friendly (e.g., liquor stores, strip clubs), then they might deter walking. Safety and fear of crime are important issues related to walkability.[32,33] The businesses in a predominantly African-American neighborhood may differ from those typically found in white mixed-use communities.[34] The counterintuitive finding that more mix of uses is associated with less walking further highlights the need for studies examining walking in communities where minority populations reside.[6]

Several limitations of this study need to be recognized. As mentioned, the lack of information regarding the types of businesses in the neighborhoods limits the ability to clearly interpret the finding that increases in mixed use were associated with less walking. In addition, data-availability constraints led to the use of less-than-ideal data (i.e., CTPP) to develop measures of land-use mix. Moreover, because the sample was not randomly selected, findings may not be generalizable to the broader population. The modest sample size also limited the statistical power of the study. Although the within-subjects design of the longitudinal study bolstered statistical power, perhaps with a larger sample more significant results would emerge. The use of pedometer-based walking data prevented an examination of the effects of neighborhood design on walking for different purposes (i.e., recreation versus destination). Finally, tests of GIS-based environmental measures ideally should be based on multiple scales, ranging from finer-grained walkable environment to more broadly defined neighborhoods.

These results suggest that the neighborhood design features (e.g., front porches, sidewalks, and shallow setbacks) may not be sufficient to affect walking, particularly when these features do not work in connection with accessibility afforded by land-use mix and street-network patterns in a broader context. Just having houses with neo-traditional façades may not be enough to increase the amount of walking done by neighborhood residents.

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