Urban Form and Psychosocial Factors: Do They Interact for Leisure-Time Walking?

MARIËLLE A. BEENACKERS, CARLIJN B. M. KAMPHUIS, RICHARD G. PRINS, JOHAN P. MACKENBACH, ALEX BURDORF, and FRANK J. VAN LENTHE

Department of Public Health, Erasmus University Medical Center, Rotterdam, THE NETHERLANDS

ABSTRACT

BEENACKERS, M. A., C. B. M. KAMPHUIS, R. G. PRINS, J. P. MACKENBACH, A. BURDORF, and F. J. VAN LENTHE. Urban Form and Psychosocial Factors: Do They Interact for Leisure-Time Walking? *Med. Sci. Sports Exerc.*, Vol. 46, No. 2, pp. 293–301, 2014. **Introduction**: This cross-sectional study uses an adaptation of a social–ecological model on the hierarchy of walking needs to explore direct associations and interactions of urban-form characteristics and individual psychosocial factors for leisure-time walking. **Methods**: Questionnaire data (n = 736) from adults (25–74 yr) and systematic field observations within 14 neighborhoods in Eindhoven (the Netherlands) were used. Multilevel logistic regression models were used to relate the urban-form characteristics (accessibility, safety, comfort, and pleasurability) and individual psychosocial factors (attitude, self-efficacy, social influence, and intention) to two definitions of leisure-time walking, that is, any leisure-time walking and sufficient leisure-time walking according to the Dutch physical activity norm and to explore their interactions. **Results**: Leisure-time walking was associated with psychosocial factors but not with characteristics of the urban environment. For sufficient leisure-time walking, interactions between attitude and several urban-form characteristics were found, indicating that positive urban-form characteristics contributed toward leisure-time walking only in residents with a less positive attitude toward physical activity. In contrast, living in a neighborhood that was accessible for walking was stronger associated with leisure-time walking among residents who experienced a positive social influence to engage in physical activity compared with those who reported less social influence. **Conclusions**: This study showed some evidence for an interaction between the neighborhood environment and the individual psychosocial factors in explaining leisure-time walking. The specific mechanism of interaction may depend on the specific combination of psychosocial factor and environmental factor. The lack of association between urban form and leisure-time walking could be partly due to the little variation in urban-form characteristics between neighborhoods. **Key Words:** ENVIRONMENT, NEIGHBORHOOD, PHYSICAL ACTIVITY, INTERACTION

Physical inactivity is a major health concern in developed countries (4,7,8,41). Leisure-time walking is promising as a focus for public health interventions to increase physical activity because it is possible for the majority of the population, it does not require any financial means, and it can be continued into old age. Increasing walking in the population can therefore comprise a substantial public health gain (27).

Leisure-time walking is determined both by individual factors (e.g., attitudes or self-efficacy) and environmental factors (e.g., neighborhood aesthetics) (20,26,31,32,35,44). Studies on environmental and individual determinants of walking pose at least two challenges (18). First, not all environmental determinants may be equally important in the decision process underlying walking. Although it seems not plausible that all neighborhood factors bear the same impact on the decision to walk, this relative importance has been studied rarely (16). This information is important to design neighborhoods that facilitate leisure-time walking. Second, the way in which environmental and individual factors interplay in determining walking is still poorly understood. Despite recognition of the social–ecological nature of walking (33), only few have studied the interplay between environmental and individual factors. In recent studies on interactions between environmental factors and individual psychosocial factors in leisure-time walking, Carlson et al. (5), Van Dyck et al. (38), and Ding et al. (13) found interactions in which a positive neighborhood environment contributed more to walking in persons with more negative psychosocial factors toward walking. Rhodes et al. (30), on the other hand, found a more synergistic relation between land-use mix and intention for walking, whereby the association between intention and walking was stronger in those perceiving closer access to recreation facilities. Cerin et al. (9) also studied leisure-time walking and did not find any interactions between neighborhood environment factors

Address for correspondence: Mariëlle A. Beenackers, Ph.D., Department of Public Health, Erasmus University Medical Center, Rotterdam, PO Box 2040, 3000 CA Rotterdam, The Netherlands; E-mail: m.beenackers@erasmusmc.nl.

Submitted for publication October 2012.

Accepted for publication July 2013.

Supplemental digital content is available for this article. Direct URL citations appear in the printed text and are provided in the HTML and PDF versions of this article on the journal's Web site (www.acsm-msse.org).

0195-9131/14/4602-0293/0

MEDICINE & SCIENCE IN SPORTS & EXERCISE®

DOI: 10.1249/MSS.0000000000000017

and self-efficacy or enjoyment. So far, the evidence on neighborhood–psychosocial interactions is emerging but still scarce and does not show a consistent pattern.

Alfonzo (2) described a framework on the hierarchy of walking needs that could provide guidance in addressing these two important challenges. First, it proposes a hierarchy of urban-form characteristics that are expected to influence walking behavior. The levels in the hierarchy are antecedents of one another so that a lower-level need should be satisfactorily fulfilled before a higher-order level is considered. Second, it places this hierarchy in a social–ecological perspective that provides concrete hypotheses on how the association between these urban-form characteristics and walking could be influenced by individual factors.

The framework departs from the idea that walking is an individual choice and identifies five levels of factors potentially and hierarchically involved in the walking decision-making process (see Fig. 1). The most fundamental level within this "hierarchy of walking needs" is the ability of people to walk, labeled *feasibility*. The other four levels within the hierarchy relate to the urban form and are labeled, in order of importance, *accessibility*, *safety*, *comfort*, and *pleasurability*. The core assumption of the hierarchical structure is that higher-order needs will not typically be considered if more basic needs have not yet been satisfied. The hierarchy also implies that the probability to walk will increase if more levels within the hierarchy are fulfilled. In addition, however, what is considered satisfactory and how many levels need to be satisfactory to engage in walking is supposed to be moderated by individual factors, for example, psychosocial factors such as attitudes or self-efficacy. Alfonzo (2) hypothesizes that when a person has less favorable psychosocial factors toward walking (e.g., is less motivated to walk), more levels within the hierarchy would need to be satisfactory to decide to walk.

The aim of this study was to explore how urban-form characteristics and individual psychosocial factors are associated with leisure-time walking and to explore neighborhood–psychosocial interactions for leisure-time walking, following Alfonzo's (2) framework on the hierarchy of walking needs.

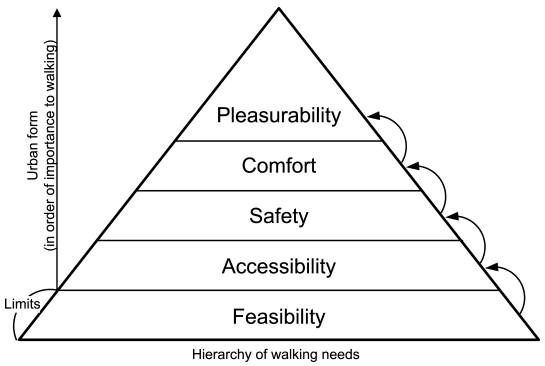

FIGURE 1—Hierarchy of walking needs. Adapted from Alfonzo (2). Reprinted with permission from SAGE Publications.

METHODS

Design and Data Collection

This cross-sectional study used questionnaire data on potential individual correlates of walking that were collected as part of the fourth wave (October 2004) of the Dutch GLOBE study in a stratified sample of the adult population of the city of Eindhoven and its surrounding municipalities (N = 6377; response 64.4%). More detailed information on the objectives, study design, and data collection of the GLOBE study can be found elsewhere (25,39,40). In February 2006, objective neighborhood data were collected in 14 neighborhoods in the city of Eindhoven. To maximize variability in neighborhood characteristics, data were collected in seven of the most deprived and seven of the most affluent neighborhoods, in which 814 study participants resided. Neighborhood socioeconomic status (SES) was based on the NIVEL (Netherlands Institute for Health Services Research) deprivation index, which is calculated from the proportion of economically nonactive, average income per income earner, proximity index, and the proportion of residents from non-Western origin (37). The neighborhood was defined as the smallest geographical unit in the Netherlands created for statistical and administrative purposes. These neighborhoods have on average 2000 residents and vary in size between 0.5 and 1.0 km^2. Respondents for whom information on walking behavior was missing (n = 37) or for whom more than a quarter of the values on the individual variables used in the analyses were missing (n = 41) were omitted from the analyses. Thus, a total of 736 respondents were included (mean number of respondents per neighborhood n = 53, ranging from 20 to 95). Under the Dutch law for medical-scientific research (WMO), ethical approval of this type of noninvasive survey research is not required. The participants were not asked to actively sign an informed consent form, but the background and objectives of the study were communicated on the first page of the questionnaire and in the accompanying invitation letter. Completion of the questionnaire was voluntary. The use of personal data in the GLOBE study is in compliance with the Dutch Personal Data Protection Act and the Municipal Database Act and has been registered with the Dutch Data Protection Authority (number 1248943).

Measures

Leisure-time walking. Leisure-time walking was assessed using the Short Questionnaire to Assess Health-Enhancing Physical Activity, a validated Dutch questionnaire that measures several specific types of physical activity, including leisure-time walking (43). Because of the skewed distribution of walking, the variable was dichotomized in two outcomes. The first dichotomous measure (labeled *any leisure-time walking*) indicated any participation in leisure-time walking in a usual week: "yes, does walk during leisure-time (1)," versus "no, does not walk at all

during leisure-time (0)." The second dichotomous outcome (labeled *sufficient leisure-time walking*) indicated whether someone walked sufficiently to reach the Dutch physical activity norm (23) of at least 5 $d \cdot wk^{-1}$ for at least 30 $min \cdot d^{-1}$. This outcome measure was coded as "yes, walks 5 days or more a week for at least 30 minutes a day (1)" and "no, does not walk, or walks less than 5 days a week for at least 30 minutes a day (0)."

Individual psychosocial factors. Individual psychosocial factors were based on theories such as the theory of planned behavior (1), the social cognitive theory (3), and the attitude, social influence, and self-efficacy model (11,24). The latter model integrates concepts of both the theory of planned behavior and the social cognitive theory. Attitude (11 items, Cronbach's alpha = 0.79), self-efficacy (2 items, Cronbach's alpha = 0.80), and intention (1 item) toward sufficient physical activity were measured on a five-point ordinal scale, and social influence on sufficient physical activity (three items referring to social norms, social support, and modeling, Cronbach's alpha = 0.72) was measured on a three-point ordinal scale. They were all formulated toward "sufficient physical activity in line with recommended levels." An overview of the items can be found in Table S1, Supplemental Digital Content, http://links.lww.com/MSS/A346. For all psychosocial factors (except intention), a mean score was calculated. A higher score on each scale represented a more positive psychosocial factor toward physical activity.

Feasibility. Feasibility, the bottom layer of Alfonzo's (2) hierarchy of walking and an individual indicator of whether someone is able to walk or not, was operationalized using the question "Are you able to walk for 400 meters at once, without stopping (if necessary with a walking aid)?" Respondents who indicated they were able with no or little difficulty were coded as "walking is feasible." Respondents who indicated that they were not able or with great difficulty were coded as "walking is not feasible."

Urban form. Information about the four urban-form levels of the hierarchy of walking needs (accessibility, safety, comfort, and pleasurability) was obtained by field observations in February 2006. An environmental audit tool, which was based on other instruments (6,10,29,42,46), was used for this purpose. Its development has been described in more detail elsewhere (21,22). Briefly, for each neighborhood, 10% of the total number of streets in the neighborhood was randomly selected, with a minimum of three streets per neighborhood. It resulted in a total of 75 audited streets. Interrater reliability was moderate to good (34), ranging from 67% to 97% with a mean of 78%. The scores on the street level items were aggregated to obtain the scores per neighborhood for each item.

The first urban-form level, *accessibility*, is defined by Alfonzo (2) to reflect "the pattern, quantity, quality, variety and proximity of activities present, as well as the connectivity between the uses" (19). In terms of access to facilities, accessibility is not strongly associated with leisure-time walking (19,31). There is stronger evidence for the association between walking infrastructure and leisure-time walking (31). Therefore, accessibility was operationalized in this study by two items measuring the presence and the quality of the available sidewalks (Cronbach's alpha = 0.57). The second urban-form level, *safety*, defined by Alfonzo (2) as whether a person feels safe from the threat of crime, was operationalized by eight items that indicated either presence of incivilities or disorder (presence of graffiti, litter on the streets, and signs of alcohol or drugs) or physical features that would provide surveillance of the street (houses for sale, empty houses, street lighting, height of fences, and visibility of the street from surrounding houses) (Cronbach's alpha = 0.73). These items are thought to influence safety from crime or fear of crime (15,45). The third urban-form level, *comfort*, was defined by Alfonzo (2) as the "level of ease, convenience, and contentment" of a person and includes traffic safety. Because of lack of information on other comfort elements such as benches and canopies, comfort was operationalized as traffic safety by four items (the presence of traffic signs, crossovers, and speed bumps and whether traffic was through traffic or only destination traffic) (Cronbach's alpha = 0.72). The final urban-form level, *pleasurability*, was defined by Alfonzo (2) as "the level of appeal that a setting provides with respect to a person's walking experience." It was operationalized by six items on the aesthetics of the neighborhood (maintenance of best buildings, maintenance of worst buildings, whether there are gardens with all houses, maintenance of the best maintained gardens, green diversity, and green maintenance) (Cronbach's alpha = 0.86) (28). More details on the items used to construct the urban-form level scales can be found in Table S2, Supplemental Digital Content, http://links.lww.com/MSS/A347.

Hierarchy score. To test whether the urban-form levels were ordered hierarchically, as the theoretical model suggests, a hierarchy score was constructed. First, all urban-form characteristics were dichotomized (1 = highest three quartiles, 0 = lowest quartile). These dichotomies were used to construct the hierarchy score that runs from 0 (none of the urban-form levels within the highest three quartiles) to 4 (all urban-form levels within the highest three quartiles). A neighborhood could only proceed to a higher hierarchy score when all lower-level urban-form levels were also "high" (within the highest three quartiles). For example, a hierarchy score of 2 would indicate that the lowest two levels (accessibility and safety) received as score "high" and that the third level (comfort) in the neighborhood would have a "low" score. A score of 2 does not give information on the highest level in the hierarchy (pleasurability). Neighborhoods with the same hierarchy level score are allowed to vary with respect to the higher-order urban-form levels. The sensitivity of the definition of the hierarchy score was investigated by using different cutoff values (tertile, median). The results remained similar.

Demographics. Potential confounders included were sex, age, country of origin (the Netherlands, other country),

TABLE 1. Characteristics of the GLOBE study according to neighborhood SES (n = 736).

Characteristics	Total (n = 736) Pct.	Seven Low SES Neighborhoods (n = 345) Pct.	Seven High SES Neighborhoods (n = 391) Pct.	P
Neighborhood SES				
Low	46.9	100		
High	53.1		100	
Any leisure-time walking				
No	36.3	37.4	35.3	
Yes	63.7	62.6	64.7	0.555[b]
Sufficient leisure-time walking[a]				
No	79.2	77.1	81.1	
Yes	20.8	22.9	18.9	0.185[b]
Sex				
Male	46.7	44.6	48.6	
Female	53.3	55.4	51.4	0.283[b]
Age				
Mean ± SD	55 ± 15	59 ± 16	52 ± 14	0.000[c]
25–34	10.7	9.9	11.5	
35–44	19.6	14.5	24.0	
45–54	16.3	10.4	21.5	
55–64	22.3	21.7	22.8	
65–75	20.5	26.4	15.4	
75+	10.6	17.1	4.9	
Education				
1 low	9.9	16.2	4.4	
2	35.5	43.8	28.1	
3	21.7	13.9	28.6	
4 high	26.6	18.0	34.3	
Missing	6.3	8.1	4.6	0.000[b]
Country of origin				
Netherlands	91.6	91.6	91.6	
Other	8.4	8.4	8.4	0.987[b]
Feasibility of walking				
Able to walk 400 m	94.3	92.2	96.2	
Not able to walk 400 m	5.7	7.8	3.8	0.020[b]
Psychosocial factors, mean ± SD				
Attitude (1–5)	3.71 ± 0.57	3.59 ± 0.59	3.81 ± 0.53	<0.000[c]
Self-efficacy (1–5)	3.70 ± 0.98	3.53 ± 1.06	3.85 ± 0.87	<0.000[c]
Social influence (1–3)	2.32 ± 0.59	2.26 ± 0.59	2.37 ± 0.59	0.013[c]
Intention (1–5)	3.94 ± 1.13	3.74 ± 1.21	4.12 ± 1.02	<0.000[c]
Urban-form characteristics				
Accessibility (0–1)	0.72 ± 0.19	0.67 ± 0.05	0.76 ± 0.25	0.468[d]
Safety (0–1)	0.77 ± 0.10	0.70 ± 0.05	0.83 ± 0.10	0.070[d]
Comfort (0–1)	0.72 ± 0.16	0.65 ± 0.18	0.77 ± 0.13	0.641[d]
Pleasurability (0–1)	0.54 ± 0.19	0.42 ± 0.12	0.64 ± 0.19	0.041[d]

[a]Five or more days a week for at least 30 min of physical activity a day.
[b]P value calculated by means of chi-square, using the individual as the level of measurement.
[c]P value calculated by an independent t-test, using the individual as the level of measurement.
[d]P value calculated by an independent t-test, using the neighborhoods as the level of measurement.

and educational level (1, no education or primary education; 2, lower professional and intermediate general education; 3, intermediate professional and higher general education; 4, higher professional education and university; or 5, missing). Educational level was included as an indicator for socioeconomic status (SES) and has proven to be a good measure for SES in the Netherlands (36).

Statistical Analyses

In the included sample (n = 736), there were a total of 4% missing values varying from less than 1% to 10% for each variable. Because complete case analyses would result in a loss of 27% of the cases, these missing values were imputed using the EM method (12) from PASW version 18.0. All individual-level variables described in the Methods section (individual psychosocial factors, demographics, feasibility, and leisure-time walking) were used in the imputation model.

First, characteristics of the sample of residents of the deprived and affluent neighborhoods were described by neighborhood SES. Second, the estimates (0–1) of the urban-form characteristics and percentage of walking were calculated in each of the included neighborhoods. Subsequently, multilevel logistic regression models were used to relate the psychosocial factors, the urban-form characteristics, and the hierarchy score to both measures of leisure-time walking. Separate models were used to test the associations of each of the ten included variables with each of the two outcome measures. All models accounted for the hierarchical structure of the data by allowing intercepts to vary across neighborhoods. The adjusted models were adjusted for age, sex, educational level, country of origin, and feasibility of walking. Interactions of individual psychosocial factors with urban-form characteristics or with the hierarchy score were tested in separate models, by adding the interaction term between a certain psychosocial factor and an urban-form characteristic to the adjusted model with the same

psychosocial factor and urban-form characteristic. A total of 20 interaction models were tested (four psychosocial factors times five urban form characteristics [four levels + the hierarchy score]). For the interaction of a psychosocial factor and the hierarchy score, dummy variables were created to study the interaction. To facilitate the interpretation of the interactions, the psychosocial factors and the urban-form characteristics were standardized (mean = 0, SD = 1). The significance throughout this study was interpreted using the 95% confidence interval (CI). All analyses were carried out in STATA 12.

RESULTS

Table 1 shows the characteristics of the total sample and according to neighborhood SES. A total of 63.7% of the sample participated in any leisure-time walking and 20.8% walked sufficiently during leisure-time to reach the Dutch physical activity norm of at least 5 $d \cdot wk^{-1}$ for at least 30 $min \cdot d^{-1}$. The large majority was able to walk for 400 m without stopping (94.3%). In the low SES neighborhoods, a higher percentage of people were unable to walk (7.8%) as compared with the high SES neighborhoods. All urban-form characteristics were more positive in the high SES neighborhoods, although only pleasurability was significantly different between the low and the high SES neighborhoods. Residents in high SES neighborhoods reported more positive psychosocial factors toward sufficient physical activity than those residing in low SES neighborhoods.

Table 2 shows the estimates of urban-form characteristics and the percentage of walking in each of the included neighborhoods. With a few exceptions, all neighborhood scores for accessibility, safety, and comfort were well higher than 0.5 on our score from 0 to 1 (median = 0.74–0.75). Pleasurability showed most diversity with almost half of the neighborhoods scoring lower than 0.5 (median = 0.51, interquartile range = 0.37–0.60).

Table 3 shows the crude and adjusted results of the multilevel logistic regression models for any leisure-time walking and for sufficient leisure-time walking. After adjustment for demographic covariates and feasibility of walking, self-efficacy (odds ratio [OR] = 1.23, 95% CI = 1.04–1.46) and intention (OR = 1.31, 95% CI = 1.12–1.54) were positively associated with any leisure-time walking. These associations were stronger for sufficient leisure-time walking as outcome (self-efficacy: OR = 1.65, 95% CI = 1.32–2.07, intention: OR = 1.48, 95% CI = 1.20–1.82). Also, a more positive attitude (OR = 1.37, 95% CI = 1.13–1.66) and a more encouraging perceived social influence toward PA (OR = 1.24, 95% CI = 1.03–1.51) were significantly associated with sufficient leisure-time walking. The separate urban-form characteristics were not associated with the walking measures, nor was the constructed hierarchy score.

Two interactions of urban-form characteristics with individual psychosocial factors were observed for sufficient leisure-time walking. The association between accessibility and sufficient leisure-time walking was more positive in those who perceived more encouraging social influence toward PA (OR = 1.20, 95% CI = 1.00–1.43; Fig. 2). The association between comfort and sufficient leisure-time walking was more positive for those with a less positive attitude toward physical activity (OR = 0.81, 95% CI = 0.66–0.99; Fig. 3). In addition, borderline significant ($P < 0.10$)

TABLE 2. Urban-form characteristics and leisure-time walking in 14 neighborhoods, stratified by socioeconomic status.

Neighborhood	n[a]	Accessibility (0–1)	Safety (0–1)	Comfort (0–1)	Pleasurability (0–1)	Hierarchy Score (0–4)[b]	Any Leisure-Time Walking (% Yes)	Sufficient Leisure-Time Walking (% Yes)[c]
High SES neighborhoods						Mean: 2.29		
Achtse Barrier–Guntselaer	71	0.25	0.85	0.75	0.61	0	57.8	19.7
Achtse Barrier–Spaaihoef	64	0.90	0.88	0.95	0.67	4	53.1	20.3
Eliasterrein–Vonderkwartier	47	0.80	0.66	0.90	0.26	1	76.6	14.9
Blixembosch-Oost	93	1.00	0.94	0.78	0.88	4	66.7	24.7
Gijzenrooi	37	0.78	0.88	0.75	0.77	4	78.4	16.2
Heesterakker	49	0.80	0.75	0.55	0.53	2	63.3	12.2
Irisbuurt	30	0.80	0.68	0.60	0.51	1	66.7	16.7
Low SES neighborhoods						Mean: 1.86		
Blaarthem	41	0.70	0.63	0.80	0.26	1	61.0	9.7
Hagenkamp	37	0.70	0.78	0.65	0.58	4	64.9	18.9
Kronehoef	64	0.70	0.73	0.35	0.50	2	54.7	15.6
Sintenbuurt	23	0.70	0.70	0.85	0.37	3	47.8	4.4
Tivoli	20	0.80	0.73	1.00	0.13	3	60.0	40.0
Vlokhoven	65	0.60	0.75	0.60	0.38	0	64.6	27.7
Woenselse Heide	95	0.64	0.66	0.71	0.48	0	70.5	32.6
Neighborhood median (interquartile range)		0.74 (0.70–0.80)	0.74 (0.68–0.83)	0.75 (0.61–0.84)	0.51 (0.37–0.60)			

[a]Number of surveyed residents in each neighborhood.
[b]Interpretation of hierarchy level scores: 0, neighborhood does not have a high level for accessibility (and the level of other characteristics varies); 1, neighborhood has a high level for accessibility, but not for safety (and the level of comfort and pleasurability varies); 2, neighborhood has a high level for accessibility and safety, but not for comfort (and the level of pleasurability varies); 3, neighborhood has a high level for accessibility, safety, and comfort, but not for pleasurability; 4, neighborhood has a high level for all four neighborhood characteristics. Note: a high level is defined as a value within the top three quartiles.
[c]Five or more days a week with at least 30 min of physical activity a day.

TABLE 3. Crude and adjusted OR for sufficient leisure-time walking[a] and any leisure-time walking (n = 736).

	Any Leisure-Time Walking				Sufficient Leisure-Time Walking[a]			
	Crude		Adjusted[b]		Crude		Adjusted[b]	
Predictors	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**	**OR**	**95% CI**
Individual level								
Feasibility								
Not able to walk for 400 m (able = ref.)	0.30	0.15–0.57***	0.27	0.14–0.53***	0.72	0.31–1.68	0.62	0.26–1.47
Psychosocial factors								
Attitude[c]	1.19	1.02–1.39*	1.13	0.97–1.33	1.33	1.11–1.61**	1.37	1.13–1.66**
Self-efficacy[c]	1.31	1.13–1.53***	1.23	1.04–1.46*	1.56	1.26–1.92***	1.65	1.32–2.08***
Social influence[c]	1.14	0.98–1.32	1.16	0.99–1.36	1.23	1.02–1.49*	1.24	1.03–1.51*
Intention[c]	1.34	1.15–1.56***	1.31	1.12–1.54**	1.41	1.15–1.73**	1.48	1.20–1.82***
Neighborhood level								
Urban form								
Accessibility[c]	1.06	0.89–1.27	1.05	0.88–1.25	0.99	0.75–1.30	1.01	0.77–1.32
Safety[c]	0.96	0.80–1.14	0.94	0.79–1.11	1.08	0.82–1.42	1.10	0.84–1.44
Comfort[c]	1.03	0.87–1.22	1.03	0.87–1.22	1.08	0.84–1.40	1.11	0.87–1.42
Pleasurability[c]	1.01	0.85–1.21	0.99	0.83–1.18	1.02	0.79–1.31	1.03	0.80–1.33
Hierarchy level score								
4	1.00		1.00		1.00		1.00	
3	0.63	0.32–1.23	0.67	0.34–1.32	0.98	0.44–2.19	0.98	0.43–2.23
2	0.77	0.48–1.24	0.78	0.49–1.26	0.61	0.33–1.13	0.58	0.31–1.09
1	1.20	0.74–1.95	1.16	0.72–1.88	0.58	0.32–1.08	0.59	0.32–1.10
0	1.02	0.68–1.51	1.06	0.71–1.57	1.39	0.91–2.14	1.33	0.85–2.07

[a]Five or more days a week with at least 30 min of physical activity a day.
[b]Adjusted models were adjusted for feasibility (being able to walk for at least 400 m), age, sex, educational level, and ethnicity.
[c]All individual psychosocial factors and urban-form characteristics were standardized for ease of interpretation (mean = 0, SD = 1).
*P < 0.050, **P < 0.010, ***P < 0.001.

interactions were found between attitude and the other urban-form characteristics (attitude–accessibility: OR = 0.84, 95% CI = 0.69–1.02; attitude–safety: OR = 0.83, 95% CI = 0.69–1.00; attitude–pleasurability: OR = 0.85, 95% CI = 0.70–1.02). Although not reaching statistical significance, these interactions were in the same direction: the association between the urban-form characteristic and sufficient leisure-time walking became more positive when attitude toward physical activity was less positive. With regard to any leisure-time walking, no significant interactions between urban-form characteristics and psychosocial factors or between the hierarchy score and psychosocial factors were found. Detailed results from the multilevel regression models that included the interaction terms can be found in Tables S3A and S3B, Supplemental Digital Content 3, http://links.lww.com/MSS/A348.

DISCUSSION

This study applied a hierarchical social–ecological perspective to leisure-time walking (2) and found that positive urban-form characteristics contributed toward leisure-time walking more in residents with a less positive attitude toward physical activity. In contrast, living in a neighborhood that was accessible for walking was more strongly associated with leisure-time walking among residents who experienced a more positive social influence to engage in physical activity

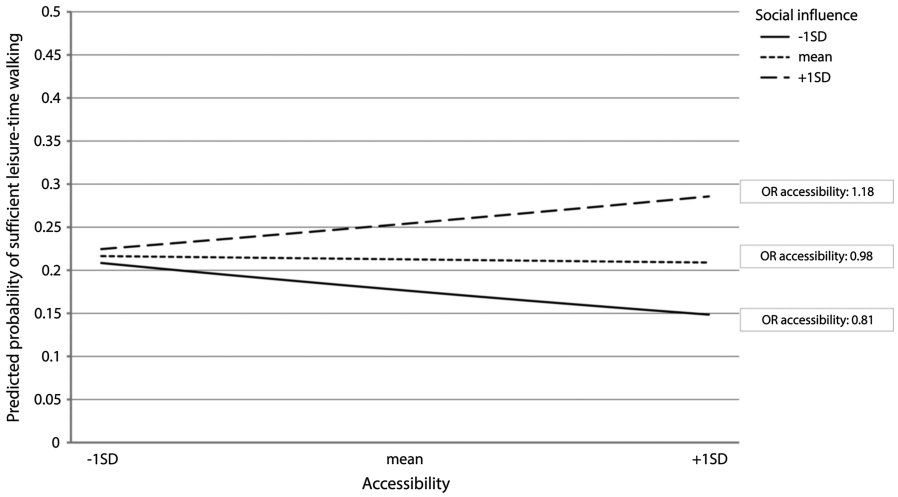

FIGURE 2—Simple slopes for the interaction between neighborhood accessibility and social influence in explaining sufficient leisure-time walking. Note: the odds ratio (OR) for an interaction term can be interpreted as a multiplicative factor. To obtain the OR for "accessibility" in each of the categories of "social influence," we multiplied the OR of the interaction term with the OR of social influence in the reference category (mean).

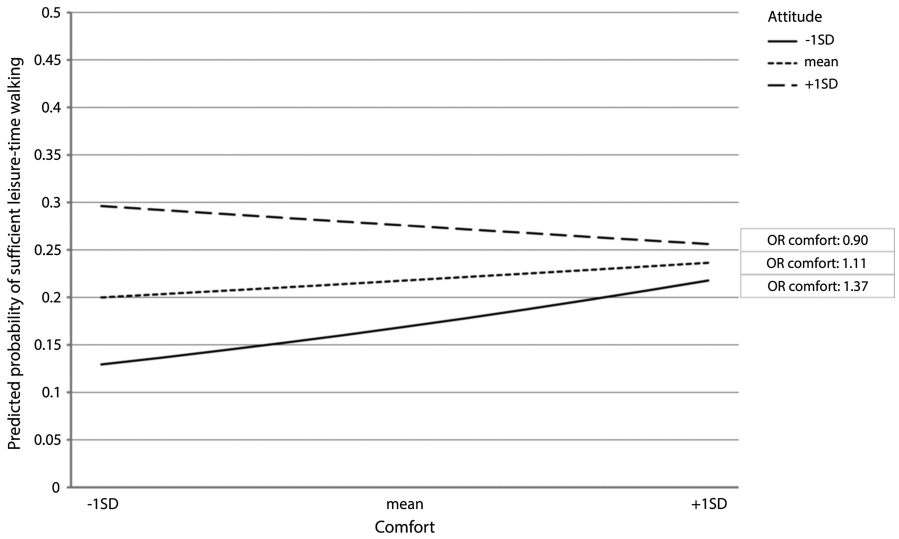

FIGURE 3—Simple slopes for the interaction between neighborhood comfort and attitude in explaining sufficient leisure-time walking. Note: the odds ratio (OR) for an interaction term can be interpreted as a multiplicative factor. To obtain the OR for "comfort" in each of the categories of "attitude," we multiplied the OR of the interaction term with the OR of attitude in the reference category (mean).

compared with those who reported less social influence. No evidence for an urban-form hierarchy was found.

The results partly support the proposed idea that psychosocial factors may moderate the association between urban form and leisure-time walking in such a way that the urban-form layout is less important among those with more positive psychosocial factors. We found several interactions in this direction between attitude and urban-form characteristics for sufficient leisure-time walking. Of the few studies that are more or less comparable with our study, the results of Ding et al. (13) also indicate that the association between neighborhood factors and leisure-time walking is stronger in those with unfavorable psychosocial factors, which is in line with our results for the interaction with attitude. Similarly, Carlson et al. (5) found that the presence of walking facilities was only associated with more leisure-time walking when self-efficacy was low. In contrast, we found a stronger association between urban accessibility and sufficient leisure-time walking among those with more supportive social influences for physical activity, which is in line with most other interactions found by Carlson et al. (5), although these interactions were for other PA outcomes than leisure-time walking. To conclude, our study is in concordance with the results from Ding et al. (13) and Carlson et al. (5) and provides evidence for interactions as proposed by the model (i.e., that the environment is less important for physical activity among those with more positive psychosocial factors). However, it also provides evidence for interactions in the other direction (i.e., that the environment is more important among those with positive psychosocial factors), indicating that both mechanisms may be at play, depending on the specific combination of psychosocial factor and environmental factor. For our second outcome, *any leisure-time walking*, no significant interactions were found, which could imply that interactions between individual and neighborhood factors are not so important for any leisure-time walking but do matter and should be further explored for public health relevant outcomes like sufficient leisure-time walking.

The results did not confirm the idea proposed in Alfonzo's (2) model that urban-form characteristics would follow a hierarchy in their association with leisure-time walking, as in the first place, no associations between urban-form characteristics and leisure-time walking were found. A possible explanation could be that, despite our efforts to maximize variability, the urban-form characteristics did not vary much across deprived and affluent neighborhoods and were generally favorable. This low variability in neighborhood design may be typical for Dutch urban areas. The Netherlands is a very dense country with very good walking and cycling infrastructure and a flat topography. Because of these favorable environmental conditions, small differences between neighborhoods may hamper finding any associations between objective environmental factors and walking behavior. As this situation seems rather specific to the Netherlands, studies in regions with less favorable neighborhood designs and more variation between neighborhoods should be conducted to test the proposed hierarchy.

Study Limitations and Strengths

The results of this study should be interpreted considering some limitations. First, the cross-sectional design impairs conclusions about causality for both the direct associations and the interactions. Second, the questions regarding the individual psychosocial factors were formulated toward "sufficient physical activity" instead of walking. This has possibly underestimated the association with leisure-time walking. Third, the neighborhood observations took place well over a year after the postal survey. The urban

innovation plans from the city of Eindhoven revealed no large urban renovations in the included neighborhoods within the time frame of the study, which strengthens our assumption that the neighborhoods have been comparable at these time points. However, some items in the safety and pleasurability scales are more transient features of the neighborhood environment, such as litter, graffiti, and maintenance of gardens, which could have resulted in some mismatch between environment and behavior. Lastly, physical activity behavior was self-reported, and we did not collect information on walking for transport, which restricted our analyses to leisure-time walking. Although this does not limit the interpretation of our results for leisure-time walking, it would be interesting to study this theoretical model with respect to walking for transport as well in future studies. In addition, the self-report measure did not include a question on where the leisure-time walking took place. This limits the interpretation of the results because those who reported to walk could have walked most often elsewhere and were, therefore, less susceptible to be influences by the urban form of their neighborhood.

The objective assessment of neighborhood factors is considered a major strength of this study because it warranted the absence of same-source bias and reporting bias that can arise when people who walk more in their neighborhood are more aware of their neighborhood. The instrument was based on previous instruments (6,10,29, 42,46) and showed adequate interrater reliability and internal consistent reliability. However, the construct validity of the used environmental audit is unknown, and it is likely that not all relevant elements of each of the hierarchy levels were included in our operationalization. Other elements of the neighborhood environment that were not operationalized could also be important for leisure-time walking. Another strength was the selection of both deprived and affluent neighborhoods that aimed to optimize the variability of the neighborhood factors. Previous studies show that neighborhoods with lower SES have less favorable neighborhood characteristics compared with neighborhoods with a higher SES (14,17), although this was not found in the city of Eindhoven. Because of the focus of this article on between-neighborhood variability, the within-neighborhood variability was not considered. If neighborhood characteristics are measured on a more individual or street level, this could increase the variation and, therefore, the understanding of individual behavior. However, it is also important to understand the between-neighborhood variation, as policies are mainly based on between-neighborhood variances. Therefore, increasing variability by including different cities or even different countries may provide useful entry points for policies and interventions.

CONCLUSIONS

To conclude, this study provided some evidence for interactions between the neighborhood environment and the individual psychosocial factors in the decision-making process for leisure-time walking. The study provided some evidence for a mechanism in which the benefits of a favorable neighborhood environment for leisure-time walking are larger for those who are less motivated to walk but also for a mechanism in which a positive physical neighborhood environment and a positive psychosocial factor can reinforce each other. The specific mechanism may depend on the specific combination of psychosocial factor and environmental factor. The lack of direct association between urban form and leisure-time walking may be partly due to little variation in urban-form characteristics between neighborhoods. This study should be replicated in other countries to gain more insight in the interplay between individual and neighborhood factors for walking and to test whether neighborhood factors act upon walking behavior following the hierarchical structure as specified by Alfonzo (2).

The GLOBE study was carried out by the Department of Public Health of the Erasmus University Medical Centre in Rotterdam, in collaboration with the public health services of Eindhoven City and the Southeast Brabant region. The study was supported by grants from the Netherlands organization for health research and development (ZonMw; number 122000003).

The authors declare there is no conflict of interest.

The present study does not constitute endorsement by the American College of Sports Medicine.

REFERENCES

1. Ajzen I. The theory of planned behavior. *Organ Behav Hum Decis Process*. 1991;50(2):179–211.
2. Alfonzo MA. To walk or not to walk? The hierarchy of walking needs. *Environ Behav*. 2005;37(6):808–36.
3. Bandura A. *Social Foundations of Thought and Action: A Social Cognitive Theory*. Englewood Cliffs (NJ): Prentice Hall; 1986. p. 617.
4. Bauman AE. Updating the evidence that physical activity is good for health: an epidemiological review 2000–2003. *J Sci Med Sport*. 2004;7(1 Suppl 1):6–19.
5. Carlson JA, Sallis JF, Conway TL, Saelens BE, et al. Interactions between psychosocial and built environment factors in explaining older adults' physical activity. *Prev Med*. 2012;54(1):68–73.
6. Caughy MO, O'Campo PJ, Patterson J. A brief observational measure for urban neighborhoods. *Health Place*. 2001;7(3):225–36.
7. Centers for Disease Control and Prevention. *Physical Activity and Health: A Report of the Surgeon General*. Washington (DC): U.S. Department of Health and Human services; 1996. p. 278.
8. Centers for Disease Control and Prevention. Physical activity and fitness. National Health Interview Survey (NHIS) [Internet]. 2008 [cited 2011 April 29]. Available from: http://wonder.cdc.gov/data2010/.
9. Cerin E, Vandelanotte C, Leslie E, Merom D. Recreational facilities and leisure-time physical activity: an analysis of moderators and self-efficacy as a mediator. *Health Psychol*. 2008;27(2 Suppl): 26–35.

10. Day K, Boarnet M, Alfonzo M, Forsyth A. The Irvine–Minnesota Inventory to measure built environments: development. *Am J Prev Med*. 2006;30(2):144–52.
11. de Vries H, Dijkstra M, Kuhlman P. Self-efficacy: the third factor besides attitude and subjective norm as a predictor of behavioural intentions. *Health Educ Res*. 1988;3(3):273–82.
12. Dempster AP, Laird NM, Rubin DB. Maximum likelihood from incomplete data via the EM algorithm. *J Roy Stat Soc B Met*. 1977; 39(1):1–38.
13. Ding D, Sallis JF, Conway TL, et al. Interactive effects of built environment and psychosocial attributes on physical activity: a test of ecological models. *Ann Behav Med*. 2012;44(3):365–74.
14. Estabrooks PA, Lee RE, Gyurcsik NC. Resources for physical activity participation: does availability and accessibility differ by neighborhood socioeconomic status? *Ann Behav Med*. 2003;25(2): 100–4.
15. Foster S, Giles-Corti B, Knuiman M. Neighbourhood design and fear of crime: a social–ecological examination of the correlates of residents' fear in new suburban housing developments. *Health Place*. 2010;16(6):1156–65.
16. Frank LD, Kerr J, Sallis JF, Miles R, Chapman J. A hierarchy of sociodemographic and environmental correlates of walking and obesity. *Prev Med*. 2008;47(2):172–8.
17. Franzini L, Taylor W, Elliott MN, et al. Neighborhood characteristics favorable to outdoor physical activity: disparities by socioeconomic and racial/ethnic composition. *Health Place*. 2010; 16(2):267–74.
18. Giles-Corti B, Timperio A, Bull F, Pikora T. Understanding physical activity environmental correlates: increased specificity for ecological models. *Exerc Sport Sci Rev*. 2005;33(4):175–81.
19. Handy SL. Understanding the link between urban form and nonwork travel behavior. *J Plan Educ Res*. 1996;15(3):183–98.
20. Humpel N, Owen N, Leslie E. Environmental factors associated with adults' participation in physical activity: a review. *Am J Prev Med*. 2002;22(3):188–99.
21. Kamphuis CBM. *Explaining Socioeconomic Inequalities in Health Behaviours—The Role of Environmental Factors*. Rotterdam: Erasmus University Medical Centre; 2008. p. 290.
22. Kamphuis CBM, Mackenbach JP, Giskes K, Huisman M, Brug J, van Lenthe FJ. Why do poor people perceive poor neighbourhoods? The role of objective neighbourhood features and psychosocial factors. *Health Place*. 2010;16(4):744–54.
23. Kemper HCG, Ooijendijk WTM, Stiggelbout M. Consensus about the Dutch recommendation for physical activity to promote health [Consensus over de Nederlandse Norm voor Gezond Bewegen]. *Tijdschrift voor Gezondheidswetenschappen*. 2000;78:180–3.
24. Kok G, de Vries H, Mudde AN, Strecher VJ. Planned health education and the role of self-efficacy: Dutch research. *Health Educ Res*. 1991;6(2):231–8.
25. Mackenbach JP, van de Mheen H, Stronks K. A prospective cohort study investigating the explanation of socio-economic inequalities in health in the Netherlands. *Soc Sci Med*. 1994;38(2):299–308.
26. Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. Understanding environmental influences on walking: review and research agenda. *Am J Prev Med*. 2004;27(1):67–76.
27. Physical Activity Guidelines Advisory Committee. *Physical Activity Guidelines Advisory Committee Report, 2008*. Washington (DC): U.S. Department of Health and Human Services; 2008. p. 683.
28. Pikora T, Giles-Corti B, Bull F, Jamrozik K, Donovan R. Developing a framework for assessment of the environmental determinants of walking and cycling. *Soc Sci Med*. 2003;56(8):1693–703.
29. Pikora TJ, Bull FC, Jamrozik K, Knuiman M, Giles-Corti B, Donovan RJ. Developing a reliable audit instrument to measure the physical environment for physical activity. *Am J Prev Med*. 2002; 23(3):187–94.
30. Rhodes RE, Brown SG, McIntyre CA. Integrating the perceived neighborhood environment and the theory of planned behavior when predicting walking in a Canadian adult sample. *Am J Health Promot*. 2006;21(2):110–8.
31. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc*. 2008;40(7 Suppl):S550–66.
32. Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. *Ann Behav Med*. 2003;25(2): 80–91.
33. Sallis JF, Owen N. Ecological models of health behavior. In: K Glanz, BK Rimer, and FM Lewis, editors. *Health Behavior and Health Educaton. Theory, Research, and Practice*. San Fransisco: Jossey-Bass; 2002. p. 462–84.
34. Stemler SE. A comparison of consensus, consistency, and measurement approaches to estimating interrater reliability. Practical Assessment, Research & Evaluation [Internet]. 2004 [cited 2012 May 21];9(4). Available from: http://pareonline.net/getvn.asp?v=9&n=4.
35. Trost SG, Owen N, Bauman AE, Sallis JF, Brown W. Correlates of adults' participation in physical activity: review and update. *Med Sci Sports Exerc*. 2002;34(12):1996–2001.
36. van Berkel-van Schaik AB, Tax B. *Towards a standard operationalisation of socioeconomic status for epidemiological and socio-medical research [Naar een standaardoperationalisatie van sociaal-economische status voor epidemiologisch en sociaal-medisch onderzoek]*. Rijswijk: Ministerie van Welzijn, Volksgezondheid en Cultuur 1990. 129 p. Available from: Ministerie van Welzijn, Volksgezondheid en Cultuur.
37. van der Velden J, Rash P, Reijneveld SA. Identification of deprived areas. A system for the distribution of extra resources to general practitioners [Identificatie van achterstandsgebieden. Een systematiek voor de verdeling van extra middelen aan huisartsen]. *Ned Tijdschr Geneeskd*. 1997;141(14):693–7.
38. Van Dyck D, Deforche B, Cardon G, De Bourdeaudhuij I. Neighbourhood walkability and its particular importance for adults with a preference for passive transport. *Health Place*. 2009;15(2): 496–504.
39. van Lenthe FJ, Kamphuis CB, Beenackers MA, et al. Cohort profile: understanding socioeconomic inequalities in health and health behaviours: the GLOBE study [published online ahead of print May 27, 2013]. *Int J Epidemiol*. doi: 10.1093/ije/dyt040.
40. van Lenthe FJ, Schrijvers CTM, Droomers M, Joung IMA, Louwman MJ, Mackenbach JP. Investigating explanations of socio-economic inequalities in health: the Dutch GLOBE study. *Eur J Public Health*. 2004;14(1):63–70.
41. Warburton DE, Nicol CW, Bredin SS. Health benefits of physical activity: the evidence. *Can Med Assoc J*. 2006;174(6):801–9.
42. Weich S, Burton E, Blanchard M, Prince M, Sproston K, Erens B. Measuring the built environment: validity of a site survey instrument for use in urban settings. *Health Place*. 2001;7(4):283–92.
43. Wendel-Vos GCW, Schuit AJ, Saris WHM, Kromhout D. Reproducibility and relative validity of the short questionnaire to assess health-enhancing physical activity. *J Clin Epidemiol*. 2003;56(12): 1163–69.
44. Wendel-Vos W, Droomers M, Kremers S, Brug J, van Lenthe F. Potential environmental determinants of physical activity in adults: a systematic review. *Obes Rev*. 2007;8(5):425–40.
45. Wood L, Shannon T, Bulsara M, Pikora T, McCormack G, Giles-Corti B. The anatomy of the safe and social suburb: an exploratory study of the built environment, social capital and residents' perceptions of safety. *Health Place*. 2008;14(1):15–31.
46. Zenk SN, Schulz AJ, Mentz G, et al. Inter-rater and test–retest reliability: methods and results for the neighborhood observational checklist. *Health Place*. 2007;13(2):452–65.