Published in final edited form as:
Am J Health Promot. 2004 ; 18(6): 435–443.

Concepts Guiding the Study of the Impact of the Built Environment on Physical Activity for Older Adults: A Review of the Literature

Grazia O. Cunningham and
Graduate Research Assistant in the Department of Public Health and Preventive Medicine, Oregon Health and Science University, Portland, Oregon

Yvonne L. Michael, ScD
Assistant Professor in the Department of Public Health and Preventive Medicine, Oregon Health and Science University, Portland, Oregon

Abstract

Objective—To identify theoretical models and key concepts used to predict the association between built environment and seniors' physical activity on the basis of a comprehensive review of the published literature.

Data Source—Computer searches of Medline (1966–2002), PubMed (1966–2002), and Academic Search Elite (1966–2002) were conducted, and 27 English-language articles were found. Search terms included built environment, physical activity, exercise, walking, neighborhood, urban design, seniors, aging, aging in place, and physical environment.

Study Inclusion and Exclusion Criteria—The primary inclusion criterion included the relation between the built environment and the physical activity among seniors living in neighborhoods. Studies assessing physical activity or overall health of a community-based population were included if underlying theoretical models and concepts were applicable to a senior population. Studies solely assessing social or psychosocial characteristics of place were excluded, as were review articles.

Data Extraction—Extracted data included theoretical model, aspect of built environment studied, methods, and outcomes.

Data Synthesis—Tables present key definitions and summarize information from empirical studies.

Results—Twenty-seven articles that focused on the environment-behavior relation in neighborhoods, six specific to seniors, were found. This area of research is in its infancy, and inconsistent findings reflect difficulties in measurement of the built environment.

Conclusions—The relation between the built environment and the physical activity among seniors has been the subject of a limited number of studies. The choice of theoretical model drives the selection of concepts and variables considered. Safety, microscale urban design elements, aesthetics, and convenience of facilities are consistently studied across models. Few validated instruments have been developed and tested to measure neighborhood built environment.

Send reprint requests to Yvonne L. Michael, ScD, Assistant Professor, Department of Public Health and Preventive Medicine, Oregon Health and Science University, 3181 SW Sam Jackson Park Road, CB-669, Portland, OR 97201.

Keywords

Built Environment; Seniors; Walking; Physical Activity

INTRODUCTION

Published literature from multiple disciplines was reviewed in order to identify theoretical models and key concepts used to predict the association between built environment and seniors' physical activity. In recent years, the impact of the built environment on health has received greater attention from health researchers and practitioners, as well as from policy makers and planners. The Centers for Disease Control and Prevention (CDC) implemented a nationwide effort, Active Community Environments, to promote physical activity through better community design.

This field of research is small and often excludes certain segments of the population. For instance, seniors, one segment that may be most influenced by the physical features of an environment, have been understudied.[1] Mobility, and perhaps independence, can be greatly limited by a poorly designed community, especially among people with compromised function.[2,3] When environmental obstacles hinder physical mobility, physical and mental health of community residents may suffer as well. In general, however, public health researchers and social scientists have ignored physical environment and focused on the social aspects of place and its effect on seniors. The focus of such research, however, is changing, particularly with the infusion of funding and attention from organizations, e.g., the CDC and the Robert Wood Johnson Foundation[4] (RWJ), that are interested in physical attributes of place and physical activity. In conjunction with RWJ and several other organizations, the CDC has also developed the "National Blueprint: Increasing Physical Activity Among Adults Age 50 and Older" as a guide for organizations, associations, and agencies to play strategies that increase the activity level of people age 50 and over.[5]

Increases in the proportion of people over 65, along with increases in life expectancy, require that special attention be given to seniors.[6] The importance of physical activity for healthy aging is well documented. Individuals who engage in moderate physical activity such as walking briskly for 30 minutes a day 5 days a week reduce their risk of stroke by 24%.[7] Regular physical activity also reduces the risk of high blood pressure, heart disease, colon cancer, and diabetes, as well as the risk of premature death.[8] Walking is an excellent form of physical activity for seniors because it is versatile, easy, cheap, and safe for aging bodies.[8] Yet the CDC reports about one third of people over 50 remain sedentary.[9] Neighborhoods are a particularly good place to study the environment-behavior relation in seniors because social and physical characteristics of neighborhoods may actually determine whether seniors will remain active and, thus, be able to remain in the community.[6]

This paper is intended to foster interest in this topic and highlight areas of need for future empirical research that will combine urban planning and public health concepts. The three specific aims of this review are (1) to identify and define key concepts from the literature in order to make these concepts accessible to health researchers and practitioners, (2) to identify and describe the theoretical models that can be used to define variables of interest or shape health promotion interventions, and (3) to identify the most common elements of built environment that have been measured and associated with physical activity in seniors.

Overview of Key Definitions and Theoretical Models

In the urban planning discipline, there is no consistent set of definitions for the various dimensions of the built environment.[10–14] Often, planners will create their own terminology

to describe the built environment. The built environment consists of three components: transportation systems, land development patterns, and microscale urban design (sidewalks, curbs, etc.).[10] Specific features of the built environment, e.g., presence of quality sidewalks and distance to the nearest retail store, have been widely used in both planning and health research and are important predictors of physical activity. Table 1 provides a listing of the most common definitions of key features of the built environment from the planning literature.

In addition, providing a framework from which specific variables and perhaps study design are selected and applied, theoretical models developed in planning and health fields suggest key concepts and pathways useful to the development of interventions. Defining built-environment factors that influence individual choices of travel behavior is essential for effecting change in physical activity behavior on a neighborhood level. According to travel behavior theory, the demand for travel is related to the demand for activities.[15] It has been assumed that people will choose to minimize the time and cost of travel if given a choice. Theories and evidence suggest that although time-minimization is important, other factors may supercede this, including quality of amenities, attitude, personal desire to walk or drive, age, and socioeconomic status.[15] Travel behavior theory also predicts a link between transportation infrastructure and mode of travel.[16]

Environmental press theory is one theory used to explain the built environment-behavior relation in the health field and one of specific importance to studies of seniors. This theory suggests that the environment places a certain degree of “press” or stress on individuals.[3] For example, the environment places greater stress on a less-competent senior. An extension of the press theory, neighborhood stressors, suggests that problems within a neighborhood affect overall well-being. Psychological stress resulting from such problems may influence a person’s decision to lead an active or sedentary lifestyle.

Various additional theoretical models, though not specific to seniors, may also be useful. Social learning theory, implemented in early studies,[17] emphasizes the importance of observing and modeling behaviors, attitudes, and emotional reactions of others.[18] Social cognitive theory further emphasizes the role of cognitive processes in defining behavior.[19]

Ecological theories of behavior, however, emphasize the role of the physical environment on individual behavior.[20] The presence of sidewalks, for instance, will influence whether a person will walk on a particular street. Inherent in this approach is that objective, physical features of an environment and individual factors are equally important.

Subsets within the ecological framework stress the physical aspects of the environment but add unique elements to the model. Behavior setting theory suggests that human behavior occurs in consistent patterns of regularly scheduled activities or “behavior settings.” Physical characteristics of these settings are important for influencing behaviors.[21] For example, an individual may choose to be physically active in playgrounds but be sedentary at home if there is not opportunity to exercise. Behavior choice theory proposes that human beings always choose their behavior in an attempt to satisfy one’s own basic needs. For example, if walking to the store is easier than waiting for a bus, a person may choose to walk. Ultimately, different environmental settings will affect the choices an individual makes.[20] Finally, socioecological theory combines the effects of social and physical aspects of the environment, both actual and perceived, on human behavior. For example, lack of social support combined with poor access to facilities, such as grocery stores and clinics, can inhibit physical activity.[21]

Contextual theorists and other ecological theorists believe that the properties of a place structure opportunities and constrain individual choices. Alternatively, compositional

theorists deny that geographically defined places predict health behaviors. For compositional theorists, the types of people living in a place are more influential on behavior than is the setting itself. Certain types of people, thus, live in certain types of places that either support or inhibit activities and behaviors. Social characteristics of people, such as income, race, ethnicity, or education, are more-significant predictors of health behaviors than is the geographical place.[20]

METHODS

Inclusion and Exclusion Criteria

The primary inclusion criterion was the relation between the built environment of neighborhoods and the physical activity in seniors. Given the limited number of articles on this topic (n = 6), and because the goal was to develop a search criterion that was sensitive enough to identify any article that assessed concepts and measures relevant to understanding the built environment's impact on seniors, the search was expanded to include studies that assessed physical activity more broadly among the general population in a community setting. Review articles were excluded in our search.

Studies initially included for the study totaled 75. Studies that solely assessed socioeconomic or sociocultural characteristics of place were not retained for further review (n = 46). Only those studies that attempted to or did discuss quantitative assessment of the physical environment were reviewed, leading to further exclusion of two articles.

Data Sources—Computer searches of Medline (1966–2002), PubMed (1966–2002), and Academic Search Elite (1966–2002) were conducted to examine English-language literature with the following search terms: built environment, exercise, physical activity, walking, neighborhood, urban design, seniors, aging, aging in place, and physical environment. Additional articles that appeared relevant were selected from the citation list of articles identified in the initial search. Specific journals—*Health & Place, Social Science and Medicine, American Journal of Preventive Medicine, Journal of Gerontology,* and the *American Journal of Health Promotion*—were frequently assessed for relevant articles with the same search criteria.

Data Extraction and Data Synthesis—For the purpose of this review, concepts and theories (if available), independent and dependent variables, methods, and outcomes were recorded for each article. In cases where theoretical model was not explicit, the lead author (G.O.C.) assigned theory based on description of conceptual model or hypothesis. Because the primary goal was to identify important concepts and variables in addition to useful theoretical models, we used a qualitative approach to summarize these key aspects in tables.

RESULTS

By using established criteria, we found 27 articles focusing on the environment-behavior relation in neighborhoods, with 10 focusing only on walking and 6 focusing on seniors. These articles were grouped according to theoretical model used to explain the relation between physical environment and health. Table 2 summarizes and defines the models used in these articles.

In most articles (n = 17), the author explicitly mentioned the theoretical model. Five articles used more than one theory.[20,28,30,32,35] Table 3 summarizes the key concepts included in assessment of physical environment and the type of measurement instrument used in each study.

Many urban planning studies have attempted to describe the effects of neighborhood design on travel behavior. Neighborhood is often defined by an index including suburban to traditional, transit accessibility, pedestrian accessibility, and neighborhood shopping,[22] though no single definition is consistent. Furthermore, few studies in the planning literature have applied rigorous measurement methods to test the effect of specific features of the built environment on alternative modes of travel behavior, such as walking. Therefore, the empirical research reviewed represents the contribution of researchers in health or gerontology who are interested in an environmental impact on physical activity.

Although this review highlights studies specific to seniors, details on studies that identified specific elements of the built environment linked to physical activity in the general population were included in tables because the variables that are considered or the overall study design may be useful in their application to future studies of seniors. Walking was specifically identified as an important form of physical activity because of its prevalence among people age 65 and older.[9] Table 4 summarizes the empirical studies and their findings.

Empirical Research on Seniors

Chapman and Beaudet[29] studied the influence of the social and physical environment on well-being in a sample of 224 community-residing elderly adults in Multnomah County, Oregon. Physical predictors, e.g., house type and distance to services and to city center, and their relation to physical and mental well-being (as defined by life satisfaction, physical activity level, social contacts, neighbor interaction, and neighborhood satisfaction) were measured. Interviews were conducted with the study subjects to obtain data on independent and dependent variables as well as outcomes. No statistically significant relations were found between convenience to facilities (measured via distance) or house type with self-reported activity level.[29] This study contrasts with other study findings that suggest that convenience of facilities is an important predictor of physical activity.[15,24–26,28] The authors provide a possible explanation for the lack of association between convenience of services and physical activity: (1) the rich support networks these elderly persons enjoy and (2) the presence of one other driving household member.

Booth and colleagues[25] assessed self-reported physical activity and perceived environmental factors in a randomly selected sample of 449 Australian adults aged 60 and older. Physical environmental influences included perceived accessibility to exercise equipment; safety of walking in the neighborhood; and access to various facilities used for physical activity, such as exercise hall, recreation center, cycle path, gym, or park. Self-reported physical activity was used to calculate the rate of energy expenditure per week. Sale footpaths for walking and access to local facilities were found to be associated with activity in this sample of seniors. This study demonstrates that seniors' perception of land-use mix may affect physical activity levels.

Hovell and colleagues[24] measured the relation between convenience of facilities and walking among a random sample of 2053 persons selected from the Haines Directory for San Diego. California. Walking, measured by self-reported data, was significantly associated with convenient facilities among all respondents. Additionally, older adults in the sample were more likely to walk than were younger adults in this sample. This underscores the importance of focusing on walking behavior in relation to the senior population.

King and colleagues[33] used self-reported data to examine the environmental factors associated with physical inactivity among middle-aged and older women within an ecological framework. Specifically, they examined the relation between eight environmental variables (presence of sidewalks, heavy traffic, hills, street-lights, unattended dogs,

enjoyable scenery, safety, and weather) and physical inactivity.[33] Data on 2912 women 40 years and older were collected as part of a large-scale cross-sectional survey. A modified version of the Behavioral Risk Factor Surveillance System (BRFSS) was used to survey respondents via telephone. Survey questions consisted of Likert-scaled and dichotomous (yes and no) questions. The presence of hills, unattended dogs, and lack of enjoyable scenery were associated with inactivity [33] Changing these environmental features, according to the authors, would help seniors be more active.

Wilcox and colleagues[34] examined similar environmental aspects as the previous study.[33] In this survey, 2338 urban and rural older women were compared regarding their physical activity level. Only absence of enjoyable scenery was associated with being sedentary in the rural women.[34] This study is notable because it is the only study included in this review that focused on a rural community.

Using the neighborhood stressors model, Balfour and Kaplan[35] examined the relation between neighborhood problems and incidence of overall and lower-extremity functional loss. Although not directly measuring physical activity, the study authors suggest that neighborhood problems may decrease physical activity because of diminished capacity. A total of 883 seniors aged 55 and older who participated in the Alameda County Study, an ongoing cohort study, were asked about functional loss and rated the severity of six neighborhood problems: traffic, noise, crime, litter, lighting, and public transportation. Neighborhood problems associated with the largest increase in risk were excessive noise, inadequate lighting, and heavy traffic Older persons who reported problematic neighborhood environments had a greater risk of functional deterioration. In fact, overall loss of function during the 2-year follow-up was two and a half times higher among seniors living in neighborhoods with two or more problems.

From the above studies, several themes are evident. Three of the six studies focused on accessibility to facilities. The Chapman study, however, assessed facilities more generally and did not report significant results. The remaining three studies, all guided by ecological theory, measured specific microscale and aesthetic elements. Aesthetic elements were associated with physical activity in both studies in which it was assessed. Two of the three studies reported that indicators of low safety (e.g., unattended dogs, inadequate lighting) were related to a decrease in physical activity. Only among the rural population were safety issues not significantly associated with physical activity. The aspects of the built environment that are most consistently studied—those aspects that are consistently associated with physical activity and those aspects of the built environment which demonstrate mixed results—were summarized in Table 4. Safety, aesthetics, convenience or access to facilities (exercise or general services), and microscale urban design (e.g., sidewalks present) were consistently studied.[17,24–30,32–36] Furthermore, safety and aesthetics were found to be consistently significant.[25–28,32–34,36] Microscale urban design, as indicated by sidewalks present, was found to be significant in two of the four studies.[27,36] Convenience of facilities appeared to have the most inconsistent findings among the research. In four studies,[17,29,34,35] convenience of facilities was not significantly associated with physical activity; five studies did find a significant relationship.[26–28,32,36]

Several studies identified different results within specific aspects of the built environment. Balfour and Kaplan[35] reported mixed results for different dimensions of safety; traffic was not significant, but inadequate lighting was significantly associated with a decrease in physical function. King and colleagues[33] also reported mixed results for safety; traffic, streetlights, and high crime were not significant, but unattended dogs were associated with a decrease in physical activity.[33] Sallis and colleagues[17] concluded that convenience of facilities was associated only with vigorous exercise, not with walking or strength exercise.

Inconsistent findings and mixed results for a specific environmental aspect may be due to several factors. Depending on the theoretical framework, variables may be defined differently. For example, Chapman and Beaudet[29] defined facilities in an ecological sense; included grocery stores, clinics, and pharmacies in the analysis; and found no significant association. On the other hand, Brownson and colleagues[27] focused specifically on exercise-related facilities, e.g., parks, trails, gyms, and did find a significant association between convenience of facilities and physical activity. Inconsistent findings may also result from inconsistent methods of measurement. Interestingly, convenience of facilities and sidewalks were the two built environment aspects that were most inconsistently associated with physical activity, and these aspects were also inconsistently measured. Some studies used self-reported data[17,26,27,32,34,35] whereas others used a combination of self-reported data and observational data.[28,29,36] The variable, sidewalks, was also inconsistently measured with three studies using self-reported data[27,33,34] and only one using a combination of self-reports and Geographic Information Systems (GIS) data.[36]

CONCLUSIONS

Despite the existence of pedestrian design guidelines in the planning field, surprisingly little is known as to how specific built environment features or design changes actually affect physical activity in seniors. The limited evidence suggests that the impact of the environment should not be overlooked in efforts to promote physical activity among seniors. Safety and aesthetics have been found to be consistently important to seniors, whereas microscale urban design elements (e.g., sidewalks) and convenience to facilities have had mixed importance for this population.

Research on environmental influences on physical activity among seniors is an important area of study because it can lead to interventions to improve health and better foster independence and aging-in-place among the growing senior population. For example, practitioners can plan walking programs in areas with well-lit streets, nice landscaping, and well-maintained sidewalks. Moreover, practitioners may be able to promote physical activity by encouraging people who live close to services to use alternative modes of transportation, e.g., walking or biking. Ultimately, physical activity interventions for seniors informed by use of a theoretical model that includes the role of the physical environment may be more successful than those relying solely on individual-oriented theories. Although the goal in this review is to further explain the most commonly used theories and not to recommend “the” model of choice, some models may be more useful for practical purposes. Ecological models, for instance, are most applicable to policy and health interventions, and suitable analytic methods are available to analyze ecological data.[27]

This review highlights limitations of existing research, particularly the absence of validated, consistent, and objective measures of specific features of environment. Inconsistent findings for specific elements of the built environment identified in this review may reflect differences in the way design aspects are measured rather than a lack of importance in the features studied for physical activity. For example, in the studies reviewed, access to facilities was inconsistently associated with physical activity among seniors. This may reflect different measurement techniques, e.g., self-report vs. objective measurement by using GIS. The use of objective measures in combination with self-reported data provides a richer, more accurate picture of environmental influences on physical activity among seniors. However, the process of developing an objective instrument to measure elements of the built environment should involve seniors in the community. It is important to allow opportunity for community perspective to shape instrument design because perceptions of the built environment relate to the reality of the built environment.[40]

A recent study conducted by Koepsell and colleagues[41] underscores the importance of objective measurement and empirical testing of specific design principles believed to be related to senior health outcomes. Crosswalk markings were introduced into urban design as a way to maximize the safety of the street-crossing environment for pedestrians despite limited and inconsistent research into its safety effects. The study improved upon existing research through use of a standardized environmental assessment tool to assess urban intersections. Although seniors may perceive intersections with marked crosswalks to be safer, the study found that pedestrian accidents involving seniors were highest at intersections with painted crosswalks but no traffic signals, even after controlling for other important factors such as average vehicular speed.[41]

Although limited, the evidence reviewed in this paper suggests that ecological interventions may increase physical activity among seniors. Even though it was outside the scope of this review to consider interventions (for a review of environmental and policy interventions, see Sallis and colleagues[42]), it is important to consider if such broad environmental changes are, in fact, possible. There are numerous efforts by local and state governments to develop guidelines for aging-sensitive communities across the country.[43] These communities are intended to accommodate changing needs and capabilities of seniors[44]; however, communities designed to enhance physical activity in seniors will be appropriate for residents of all ages.[45] To date, studies have shown that changes to existing environments have led to increases in the percentage of people in the general population reporting increases in leisure-time physical activity and even changes in energy expenditure.[46] Such environmental changes, however, have not been widely researched among seniors.[47]

It is imperative that environmental design be studied within an aging-specific framework, especially because seniors themselves do not value all improvements believed to increase physical activity. For example, evidence shows that the existence of sidewalks enhances physical activity among seniors. However, in municipalities like Portland, Oregon, that require residents living on an unimproved road to pay for enhancements such as sidewalks, such street improvements would create a financial burden for seniors on a fixed budget.[48] Likewise, speed bumps are encouraged in urban design to significantly reduce car speeds and increase foot traffic. However, seniors concerned about the potential delay that bumps might cause in emergency response vehemently oppose their use to calm traffic.[48] The changing needs and capabilities of seniors create unique challenges in designing communities for an aging society. Ultimately, future research is needed to understand the environmental factors that are specifically related to physical activity among seniors, and it must involve seniors in the research process to ensure that their unique perspectives arc considered.

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SO WHAT? Implications for Health Promotion Practitioners and Researchers

1. This review indicates that research on the environment-behavior relationship among seniors is limited. To date, ecological and social cognitive theoretical constructs have been most widely used in such research. Safety and aesthetics have been found to be consistently important to seniors, whereas microscale urban design elements (e.g., sidewalks) and convenience to facilities have had mixed importance for this population. On the basis of our work in the field to date, we believe these conclusions are preliminary.
2. Practitioners may encourage physical activity among seniors by developing interventions based on theoretical models useful to explain the environment-behavior relation.
3. Additionally, these findings suggest that researchers should develop a validated instrument with which to measure the built environment and frame future research so that seniors' changing needs and unique values are addressed.

Table 1

Definitions of Built Environment Features

Author	Feature of Built Environment	Definition
Frank and Engelke[10]	Transportation systems	Systems that provide connections between activities
	Land-use pattern	The arrangement of activities and the impact between trip origin and destinations
Handy et al.[11]	Density	Amount of activity in a given area
	Land-use mix	Proximity of different land uses
	Street connectivity	Directness and availability of alternative routes through a neighborhood
Hess[12]	Aesthetic qualities	Attractiveness and appeal of a place
	Connectivity	Directness and availability to different areas in a region, composed of street system, sidewalk network, pedestrian volumes, and directness of route
Rapoport[14]	Microscale elements	The number of noticeable differences in a street; also defines the level of complexity of an environment, and, thus, interest of the pedestrian

Table 2

Overview of Theoretical Models

Theoretical Model	Key Definition	Studies Using the Model
Travel behavior	Demand for activities is related to demand for travel	Frank and Engelke,[10] Handy et al.,[11] Hess,[12] Owens,[13] Rapoport,[14] Handy and Clifton,[15] Cervero and Seskin,[16] Crone and Crepeau,[22] Macyntre et al.[23]
Social learning	Human behavior results from the continuous interaction between cognitive, behavioral, and environmental influences	Sallis et al.,[17] Hovell et al.[24]
Social cognitive	Subset of social learning theory; cognitive processes are most important for behavior	Booth et al.,[25] Ball et al.,[26] Brownson et al.,[27] Troped et al.[28]
Ecological	Physical environment plays a large role in a person's choice to be physically active	Chapman and Beaudet,[29] Sallis et al.,[30] Berrigan and Troiano,[31] Steptoe and Feldman,[32] King et al.,[33] Wilcox et al.,[34] Balfour and Kaplan,[35] Lee et al.,[36] Craig et al.,[37] Troped et al.[28]
Behavior setting	Subset of ecological; human behavior occurs in consistent patterns of regularly scheduled activities or "behavior settings"	Owen et al.,[20] Sallis et al.[30]
Behavior choice theory	Humans behave according to meet their own basic needs	Owen et al.[20]
Neighborhood stressor theory	Within scope of environmental press theory; problems within a neighborhood affect behavior	Steptoe and Feldman,[32] Balfour and Kaplan[35]

Table 3

Summary of Literature on Physical Environment and Health

		Type of Measurements Used		
Author	**Aspect of Built Environment Studied**	**Self-Report**	**Observation**	**Secondary Data**
Owens[13]	Zone form, formative process, structural scale, boundaries, connectivity, microscale elements	NA		
Frank and Engelke[10]	Transportation systems, land development patterns, micro-urban scale design	NA		
Handy et al.[11]	Density/intensity, land-use mix, street connectivity, street scale, aesthetics, regional structure	NA		
Hess[12]	Connectivity	NA		
Rapoport[14]	Microscale elements and overall design	NA		
Howe[44]	Land-use mix	NA		
Owen et al.[20]	Land-use mix, microscale elements	NA		
Sallis et al.[17]	Land-use mix	X		
Hovell et al.[24]	Land-use mix	X		
Booth et al.[25]	Land-use mix	X		
Ball et al.[26]	Aesthetics and land-use mix	X		
Brownson et al.[27]	Microscale elements	X		
Troped et al.[28]	Microscale elements, land-use mix	X	X	
Chapman and Beaudet[29]	House type, aesthetics, land-use mix	X		X
LaGory M & Fitzpatrick K et al. (1992)	Land-use mix (resource accessibility)	X	X	
Sallis et al.[30]	Microscale elements, access to amenities, aesthetics	X		
Lee et al.[36]	Microscale elements, aesthetics	X	X	
King et al.[33]	Microscale elements, aesthetics	X		
Wilcox et al.[34]	Microscale elements, aesthetics	X		
Steptoe and Feldman[32]	Microscale elements, land-use mix	X		
Balfour and Kaplan[35]	Microscale elements	X		
Craig et al.[37]	Connectivity, transportation system, aesthetics, land-use mix		X	X
Berrigan and Troiano[31]	Street design, home age as proxy measure for urban form	X		
Caughy et al.[38]	Aesthetics, land-use mix	NA		
Welch et al.[39]	Land-use mix, microscale elements	NA		

* NA = not applicable.

Table 4

Review of Methods and Findings of Empirical Studies[†]

Author	Sample	Independent Variables (Built Environment Only)	Dependent Variables	Association[*]
Sallis et al.[17]	2053 adults living in San Diego	1. Neighborhood environment (safety and ease of exercising)	Self-reported vigorous exercise	NS
		2. Convenience of facilities		NS
Hovell et al.[24]	2053 adults in San Diego	1. Neighborhood environment (safety and ease of exercising)	Walking for exercise	+
Booth et al.[25]	449 Australian adults age 60 and older	1. Safety of footpaths	Physical activity	+
		2. Access to various facilities: local hall, track, golf course, gym, park, swimming pool		+
				+
				NS
				+
				+
				NS
Ball et al.[26]	3392 Australian adults	1. Aesthetics of environment	Walking	
		Moderate		−
		Low		−
		2. Convenience of facilities		
		Moderate		−
		Low		−
Brownson et al.[27]	1818 U.S. adults	1. Access to trail	Physical activity	NS
		2. Access to park		+
		3. Sidewalks present		+
		4. Enjoyable scenery		+
		5. Heavy traffic		+
		6. Hills		+
		7. Streetlights		NS
Troped et al.[28]	413 adults in Arlington, Massachusetts	8. Steep hill	Use of trail	−
		9. Distance to trail		−
		10. Lack of heavy traffic		+
		11. Residential neighborhood		−
Chapman and Beaudet[29]	224 community residing elderly adults in Portland, Oregon	1. Proximity to services	Activity level	NS
Sallis et al.[30]	110 college students	1. Neighborhood environment score (sidewalks, lack of hills, enjoyable scenery, lack of high crime rates)	a. Walking	NS
			b. Vigorous exercise	NS
			c. Strength exercise	
		2. Convenient facilities	a. Walking	NS
			b. Vigorous exercise	+
			c. Strength exercise	NS
Lee et al.[36]	128 women in San Francisco Bay area	1. Access to park	Physical activity	+
		2. Access to bike paths		+
		3. Sidewalks		+
		4. Streetlights		+
		5. Scenery		+

Author	Sample	Independent Variables (Built Environment Only)	Dependent Variables	Association*
		6. Heavy traffic		−
		7. Hills		−
		8. Unattended dogs		−
		9. High crime		−
King et al.[33]	2912 women aged 40 and older	1. Sidewalks	Physical activity	NS
		2 Heavy traffic		NS
		3. Lack of hills		+
		4. Streetlights		NS
		5. Unattended dogs		+
		6 Enjoyable scenery		+
		7. High levels of crime		NS
Wilcox et al.[34]	1242 Rural women; 1096 urban women aged 40 and older	1. Sidewalks	Physical activity	NS
		2. Heavy traffic		NS
		3 Lack of hills		NS
		4. Unattended dogs		NS
		5 Enjoyable scenery		+ (for rural only)
		6 High levels of crime		NS
		7. Easy access to rails, pools, etc.		NS
Steptoe and Feldman[32]	419 residents of high socioeconomic neighborhood; 235 residents of low socioeconomic neighborhood	1. High traffic density	Physical function	−
		2. High dirt and noise		−
		3. Absence of local facilities		−
		4. Limited local transport		−
Balfour and Kaplan[35]	883 age 55 and older living in Alameda County, California	1. Traffic	Physical function	NS‡
		2. Noise		+‡
		3. Crime		NS
		4. Trash/litter		NS
		5. Inadequate lighting		+
		6. Access to public transportation		NS
Craig et al.[37]	Convenience sample of 27 neighborhoods in Ontario, Quebec, and Alberta, Canada	Environment score consisting of:	Walking to work	+
		1. Number of destinations		
		2. Variety of destinations		
		3. Inclusive of pedestrians		
		4. Social dynamics		
		5. Walking routes		
		6. Meets pedestrian needs		
		7. Walking system		
		8. Transportation system		
		9. Complexity of stimulus		
		10. Potential “overload” of stimulus		

Author	Sample	Independent Variables (Built Environment Only)	Dependent Variables	Association*
		11. Visual interest		
		12. Visual aesthetics		
		13. Time and effort required		
		14. Traffic threats		
		15. Obstacles		
		16. Safety from crime		
		17. Potential for crime		
Berrigan and Troiano[31]	14,827 adults from the NHANES survey	Home age (homes aged 29–56 y)	Walking	+

† NS = not significant.

‡ Significant on their own and in the presence of other problems.

* $p < .05$.