Journal of Urban Health: Bulletin of the New York Academy of Medicine, Vol. 92, No. 2
doi:10.1007/s11524-014-9932-1

Do Relationships Between Environmental Attributes and Recreational Walking Vary According to Area-Level Socioeconomic Status?

Takemi Sugiyama, Natasha J. Howard, Catherine Paquet, Neil T. Coffee, Anne W. Taylor, and Mark Daniel

ABSTRACT *Residents of areas with lower socioeconomic status (SES) are known to be less physically active during leisure time. Neighborhood walkability has been shown to be related to recreational walking equally in low and high SES areas. This cross-sectional study tested whether associations of specific environmental attributes, measured objectively and subjectively, with walking for recreation were moderated by area-level SES. The data of the North West Adelaide Health Study collected in 2007 (n=1500, mean age 57) were used. Self-reported walking frequency was the outcome of the study. Environmental exposure measures included objectively measured walkability components (residential density, intersection density, land use mix, and net retail area ratio) and perceived attributes (access to destinations, neighborhood esthetics, walking infrastructure, traffic/barriers, and crime safety). Participants' suburbs were categorized into low and high SES areas using an indicator of socioeconomic disadvantage. Low SES areas had lower scores in residential density, neighborhood esthetics, walking infrastructure, traffic/barriers, and crime safety. Recreational walking was associated with residential density, access to destinations, esthetics, traffic/barriers, and crime safety. Effect modification was observed for two attributes (out of nine): residential density was associated with walking only in low SES areas, while walking infrastructure was associated with walking only in high SES areas. The associations of neighborhood environmental attributes with recreational walking were largely consistent across SES groups. However, low SES areas were disadvantaged in most perceived environmental attributes related to recreational walking. Improving such attributes in low SES neighborhoods may help close socioeconomic disparities in leisure time physical activity.*

KEYWORD *Physical activity, Neighborhood environment, Walkability, Inequality, Effect modification*

Sugiyama, Howard, Paquet, Coffee, and Daniel are with the Spatial Epidemiology and Evaluation Research Group, Sansom Institute for Health Research & School of Population Health, University of South Australia, Adelaide, SA 5001, Australia; Paquet is with the Research Centre of the Douglas Mental Health University Institute, Verdun, Canada; Taylor is with the Discipline of Medicine, The University of Adelaide, Adelaide, Australia; Daniel is with the Department of Medicine, St. Vincent's Hospital, The University of Melbourne, Melbourne, Australia; Daniel is with the South Australian Health & Medical Research Institute, Adelaide, Australia.

Correspondence: Takemi Sugiyama, Spatial Epidemiology and Evaluation Research Group, Sansom Institute for Health Research & School of Population Health, University of South Australia, Adelaide, SA 5001, Australia. (E-mail: takemi.sugiyama@unisa.edu.au)

INTRODUCTION

The residents of neighborhoods with low socioeconomic status (SES) are reported to be less physically active, relative to those living in high SES areas.[1,2] Such disparities are particularly apparent for recreational physical activity. A study in the Netherlands found that residents of low SES neighborhoods had a higher likelihood of not participating in recreational physical activity, in comparison to those of high SES areas.[3] Similarly, an Australian study showed that walking for recreation was more prevalent among participants living in high SES areas than those in low SES areas.[4] Since reducing health inequalities between low and high SES areas are recognized as a critical challenge for public health,[5] and because walking is a popular physical activity with known health benefits,[6] it is important to address the SES-related disparity in recreational walking.

Environmental initiatives to promote physical activity have promise to address this gap. Recent studies show that neighborhood walkability, an environmental measure of "ease" of walking in local areas, is associated with walking for recreation equally in low and high SES areas.[7–9] Such evidence supports the potential of environmental initiatives to increase recreational physical activity both in advantaged and disadvantaged neighborhoods. However, studies to date have focused on walkability, a composite measure of objectively derived environmental factors that are hypothesized to be related to walking, in examining how associations of neighborhood environments with physical activity may vary between low and high SES areas. It is unknown what *specific* environmental attributes are relevant to physical activity in distinct SES areas. Such knowledge is vital for developing environmental interventions that do not increase socioeconomic disparities in physical activity. In addition, little research has evaluated whether *perceptions* of neighborhood environments might be differentially related to recreational physical activity in low and high SES areas. The perceptions of surroundings play an important role in people's behavior choice within possible options provided by the built environment.[10] Perceived environmental attributes such as neighborhood esthetics[11–13] and fear of crime[14,15] are associated with recreational physical activity. It is also known that environmental perceptions do not always match objectively measured characteristics[16,17], and people of low SES tend to perceive their surroundings more negatively than those of high SES.[18] Environmental perceptions may contribute to lower levels of recreational physical activity among those living in disadvantaged areas.

In order to identify specific environmental attributes that could subsequently be modified to reduce gaps in recreational walking between low and high SES areas, this study examined associations between walking for recreation and specific objectively measured and perceived environmental attributes and tested whether these relationships are moderated by area-level SES.

METHODS

Study Sample

This study was part of the Place and Metabolic Syndrome (PAMS) project, which expands on the North West Adelaide Health Study (NWAHS). The NWAHS is a longitudinal biomedical cohort of chronic conditions and health-related risk factors, where adults over 18 years were randomly selected from the northern and western regions of metropolitan Adelaide, South Australia. Baseline data were collected in

2000–03 (n=4056), with two additional waves of data collection over 10 years.[19] This cross-sectional study used the data collected at Wave 2 (n=3563, 2004–07). Geographical data current at 2006 were used to represent objective features of environments. Data on the participants' perceptions of local environments and physical activity were collected in 2007, using a self-administered questionnaire. Of participants who took part in the relevant Wave 2 surveys (n=1943), this study focused on those who were younger than 85 years, who stayed at the same address between 2004 and 2007, and who had a valid geo-referenced address within the Adelaide Statistical Division (n=1653). The project was approved by the Human Ethics Committees of the University of South Australia, the Central Northern Adelaide Health Service, and the South Australian Department for Health and Ageing.

Outcome Variable

The outcome of the study was the frequency of recreational walking. It was determined using a single, self-reported item on the number of times participants walked for sport, recreation, or fitness in the last 2 weeks. This is a question used in the Australian National Health Survey.[20] Since walking frequency was skewed, it was categorized as no walking (0 times/week), occasional walking (0.5–4.5 times/week), and frequent walking (5+ times/week). Walking frequency was used instead of duration of walking episodes because the longer time frame of the question (last 2 weeks) may make accurate recall of duration difficult. Overreporting of duration is common in instruments (such as the International Physical Activity Questionnaire) that ask about the duration of activity in the last 7 days.[21] Recent studies have also used walking frequency, due to similar concerns about the accuracy of walking duration.[22,23]

Exposure Variables

Attributes of neighborhood environments were determined both objectively using a geographic information system (GIS) and subjectively using self-reported responses to survey questions. Objective attributes included four components of walkability: residential density, intersection density, land use mix, and net retail area ratio.[24] They were determined for each participant within a 1-km road network buffer from their home using ArcGIS software (ESRI, Redlands, CA). Residential density was calculated as the density of private dwellings in residential parcels within or intercepted by the buffer (number/km^2). Intersection density was calculated as the density of intersections (3-way or more) within the buffer area (all parcels within or intercepted by the buffer; number/km^2). For land use mix, an entropy value based on the size of three land uses (residential, retail, and recreational), which are potentially relevant to recreational walking, was calculated within the buffer area. This value ranged from 0 (single land use) to 1 (land uses equally distributed). Net retail area ratio was calculated as the proportion of total retail floor space (counting all floor space in multistory buildings) to total retail parcel area within the buffer. This measure expresses how much space exists around shops (e.g., for parking) and is an indicator of the compactness of retail areas.

Perceived environmental attributes were measured using the Neighborhood Environment Walkability Scale.[25] Participants responded to questions about their local area (defined as within a 10- to 15-min walk from home). Responses were scaled from 1 (strongly disagree) to 4 (strongly agree). Based on a previously reported factor analysis of this scale for the same sample,[26] the following five

constructs were produced from 27 items: access to destinations, neighborhood esthetics, walking infrastructure, traffic/barriers not a problem, and crime safety. A brief description of the items and internal consistency of each construct are as follows: access to destinations (shopping mostly in local area, many shops nearby, many places to go nearby, easy walk to a public transport stop; α=0.80), neighborhood esthetics (lots of greenery, tree cover along footpaths, many interesting things to look at, attractive buildings nearby, pleasant natural features nearby; α=0.73), walking infrastructure (footpaths on most streets, footpaths well maintained, parks/nature reserves nearby, grass/dirt strip separating footpaths from streets, bicycle/walking paths nearby, traffic slowing devices, pedestrian crossing and traffic signals on busy streets, street well lit at night; α=0.67), traffic/barriers not a problem (major barriers to walking, difficult/unpleasant to walk due to traffic, living near arterial roads, a lot of exhaust fumes; α=0.59), and crime safety (a lot of petty crime, a lot of major crime, unsafe to walk during the day, unsafe to walk at night, not feeling safe walking home from bus/train stops at night, not free from litter/rubbish/graffiti; α=0.79). Negative attributes that would hinder walking were reversely scored.

Potential Effect Modifier

The Index of Relative Socioeconomic Disadvantage (IRSD), extracted for State Suburbs from 2006 Australian Census for Population and Housing, was used as an area-level indicator of SES.[27] For 192 State Suburbs in the study area, the median size was 1.7 km^2 (interquartile range 1.1–3.4 km^2). Suburbs were categorized into low and high SES areas using the median split of IRSD (for those represented in the sample).

Covariates

Covariates included in the study were age, gender, educational attainment (having a Bachelor's degree or not), work status (working or not), marital status (coupled or single), and annual household income (AUD $\leq$\$30,000, \$30,001–60,000, $\geq$\$60,001).

Analysis

Multinomial logistic regression was used to estimate the odds of occasional and frequent walking (compared to no walking) according to each environmental attribute, with cluster-robust standard errors to account for nonindependence of observations within each State Suburb. Analyses first examined associations of walking with environmental attributes (each attribute examined individually) and tested interactions between each environmental attribute and area-level SES. When the interaction was significant, analyses stratified by SES levels were conducted. Models accounted for age, gender, educational attainment, work status, and annual household income (marital status was not included as it was not associated with walking). All environmental attributes were standardized prior to analysis. Analyses were conducted using Stata12 (STATA Corporation, College Station, TX). Statistical significance was set at $p<0.05$, except for interaction effects ($p<0.15$). This level of significance (0.15) was used for interactions, because interaction terms are known to be underpowered,[28] and this study aimed to screen possible interactions rather than to test hypothesized interactions.

RESULTS

The final study sample included 1500 participants following exclusion of those with missing data for outcome (n=95) or exposure (n=58) measure. Table 1 shows the sample characteristics. The median frequency of walking was 1.5 times/week (interquartile range 0–3). One third of the sample did not walk for recreation, about half walked occasionally, and less than one fifth walked frequently for recreation. These proportions differed significantly between low and high SES areas (p<0.01). In low SES areas, 37 % of participants did not walk, while 45 and 18 % of them walked occasionally and frequently. In high SES areas, 29 % were no walkers, 54 % were occasional walkers, and 17 % were frequent walkers. Table 2 shows the mean scores for objective and perceived environmental measures according to SES strata. Low SES areas had higher intersection density and land use diversity, but lower residential density, and lower perceptions of neighborhood esthetics, walking infrastructure, traffic/barriers, and crime safety, relative to high SES areas.

Table 3 shows the results of multinomial logistic regression (main effects). Higher residential density was associated with significantly higher odds of frequent walking for recreation. Those individuals perceiving better access to utilitarian destinations in their neighborhoods were more likely to walk for recreation (both occasionally and frequently). Better perceptions of neighborhood esthetics, traffic/barriers, and crime safety were also associated with a higher likelihood of recreational walking.

TABLE 1 Sample characteristics, overall, and according to walking frequency

	Total	No walking	Occasional walking[a]	Frequent walking[b]	p
n (%)	1500	499 (33)	747 (50)	254 (17)	–
Age, years	57.4 (14.0)	58.0 (14.6)	56.3 (13.7)	59.6 (13.4)	<0.01
Gender, % men	45	46	43	46	ns
Education, % with Bachelor degree	13	10	15	11	<0.05
Work status, % working[c]	51	47	56	45	<0.01
Marital status, % married or de facto	66	66	67	63	ns
Annual household income					<0.01
% ≤AU$30,000	39	44	34	45	
% AU$30,001–60,000	33	33	34	29	
% ≥AU$60,001	27	22	30	26	
% not reporting	1	1	2	0	
Area-level SES (IRSD)[d]	953 (83)	943 (84)	959 (82)	952 (79)	<0.01

Results are shown in mean (SD) or %

[a]0.5–4.5 times/week

[b]5 times/week or more

[c]Full time, part time, or casual employment

[d]Index of Relative Socioeconomic Disadvantage (lower scores denote more disadvantage)

TABLE 2 Environmental attributes, overall, and according to SES

	Total	Low SES[a]	High SES[b]	*p*
Objective measures				
Residential density (number/km^2)[c]	1330 (431)	1310 (359)	1351 (492)	<0.1
Intersection density (number/km^2)[d]	54.3 (25.8)	55.6 (23.7)	52.9 (27.7)	<0.05
Land use mix[e]	0.56 (0.16)	0.58 (0.15)	0.54 (0.17)	<0.001
Net retail area ratio (%)[f]	22.3 (13.8)	21.9 (12.6)	22.8 (15.0)	ns
Perceived measures (range 1–4)				
Access to destinations	3.07 (0.77)	3.04 (0.76)	3.10 (0.78)	ns
Neighborhood esthetics	2.84 (0.63)	2.68 (0.65)	3.01 (0.57)	<0.001
Walking infrastructure	2.89 (0.53)	2.85 (0.52)	2.92 (0.55)	<0.05
Traffic/barriers not a problem	2.90 (0.63)	2.81 (0.63)	2.98 (0.62)	<0.001
Crime safety	2.84 (0.63)	2.67 (0.63)	3.02 (0.57)	<0.001

Results are shown in mean (SD)

[a]Low: IRSD <951

[b]High: IRSD ≥951

[c]The density of dwellings in residential area within the 1 km buffer area

[d]The density of intersections (3-way or more) within the 1 km buffer area

[e]Entropy value based on the size of residential, retail, and recreational land uses

[f]The proportion of total retail floor area to total retail parcel area within the 1 km buffer area

Significant interactions were found between residential density and SES for occasional walking (p=0.11), between land use mix and SES for frequent walking (p=0.13), and between walking infrastructure and SES for frequent walking (p=0.13). Table 4 shows for these attributes the results of analyses stratified according to SES. Higher residential density was associated with occasional walking in low but not in high SES areas. Associations were not statistically significant for land use mix. Perceived walking infrastructure was not associated with walking in low SES areas but was associated with frequent recreational walking in high SES areas. Table 5 summarizes the results: differences in environmental measures for low and high SES areas, main effects, and SES-specific associations.

DISCUSSION

The aim of this study was to identify environmental attributes associated with walking for recreation, with a particular relevance to residents of low SES areas, in order to identify attributes that could be subsequently modified to encourage greater recreational walking in disadvantaged areas. Consistent with previous reports,[3,4] this study found that residents of low SES areas walked less often for recreation than those of high SES areas, confirming an area-based differential in health behavior. One objectively determined and four perceived environmental characteristics were associated with the frequency of walking for recreation. These were residential

TABLE 3 Associations between environmental attributes and walking for recreation

	Odds ratio (95 % CI)	
	Occasional walking[a] (versus non walking)	Frequent walking[b] (versus non walking)
Objective measures		
Residential density	1.07 (0.95, 1.21)	1.21 (1.04, 1.41)*
Intersection density	1.03 (0.93, 1.13)	1.17 (1.00, 1.37)
Land use mix	0.95 (0.83, 1.07)	0.97 (0.83, 1.15)
Net retail area ratio	1.10 (0.99, 1.23)	1.13 (0.96, 1.33)
Perceived measures		
Access to destinations	1.15 (1.03, 1.28)**	1.42 (1.21, 1.66)***
Neighborhood esthetics	1.09 (0.97, 1.22)	1.21 (1.07, 1.38)**
Walking infrastructure	1.05 (0.94, 1.17)	1.10 (0.96, 1.27)
Traffic/barriers not a problem	1.09 (0.97, 1.22)	1.19 (1.04, 1.37)*
Crime safety	1.16 (1.04, 1.31)*	1.10 (0.95, 1.29)

Results of multinomial logistic regression (with cluster-robust standard errors), adjusting for age, gender, education, work status, and household income. All environmental attributes were standardized and examined individually

$p<0.1$, *$p<0.05$, **$p<0.01$, ***$p<0.001$

[a]0.5–4.5 times/week

[b]5 times/week or more

density (objective) and access to destinations, neighborhood esthetics, traffic/barriers not being a problem for walking, and safety from crime (perceived). These findings generally align with previous studies that examined environmental correlates of walking.[29] Associations between these five attributes and recreational walking were not moderated by area-level SES, except for residential density being associated with walking specifically in low SES areas. Consistent with other reports indicating that walkability is associated with walking regardless of SES levels,[7–9] this study found that associations between specific environmental attributes and recreational walking are largely similar for low and high SES areas.

Low SES areas had lower scores for all environmental attributes associated with walking, except for perceived access to destinations. This means that low SES areas are disadvantaged in environmental characteristics that may facilitate residents' recreational walking. Such SES-based disparities in environmental attributes have been reported previously.[30,31] Further, four of the five attributes associated with walking in this study were perceived measures, and individuals living in low SES areas had lower scores for most perceived attributes measured. Although it has been shown that residents of lower SES areas tend to perceive their surroundings more negatively than those of higher SES areas,[18] it is unknown whether differential perceptions as these reflect actual variations in environments or variations in the ways environments are perceived. However, to reduce the gap in recreational walking between low and high SES areas, interventions that could directly or indirectly support more positive perceptions of neighborhood esthetics, traffic

TABLE 4 SES-stratified associations between environmental attributes and walking for recreation

		Odds ratio (95 % CI)	
	Area-level SES[a]	Occasional walking[b] (versus non walking)	Frequent walking[c] (versus non walking)
Objective measures			
Residential density	Low	1.21 (1.02, 1.45)*	1.17 (0.94, 1.46)
	High	1.00 (0.86, 1.18)	1.22 (0.98, 1.52)
Land use mix	Low	0.94 (0.77, 1.15)	0.85 (0.67, 1.08)
	High	0.99 (0.85, 1.15)	1.10 (0.88, 1.38)
Perceived measures			
Walking infrastructure	Low	1.06 (0.89, 1.26)	0.99 (0.80, 1.22)
	High	1.04 (0.91, 1.20)	1.23 (1.01, 1.50)*

Results of multinomial logistic regression (cluster-robust standard error) stratified by SES, adjusting for age, gender, education, work status, and household income. All environmental attributes were standardized and examined individually

$p<0.1$, *$p<0.05$

[a]Low: IRSD <951, high: IRSD ≥951

[b]0.5–4.5 times/week

[c]5 times/week or more

problems and barriers, and crime safety in low SES areas could have merit. Such interventions may involve individual, social, environmental, and policy approaches. For instance, local walking events or walking groups could help residents to discover suitable walking opportunities within their neighborhoods. Strategies to improve

TABLE 5 Summary results for environmental measures: SES difference, associations with walking, and SES-specific associations with walking

	Low/high SES difference	Main effects	SES-specific associations
Objective measures			
Residential density	Low < high	Yes	Low SES only
Intersection density	Low > high	Marginal[a]	No
Land use mix	Low > high	No	No
Net retail area ratio	No difference	Marginal[b]	No
Perceived measures			
Access to destinations	No difference	Yes	No
Neighborhood esthetics	Low < high	Yes	No
Walking infrastructure	Low < high	No	High SES only
Traffic/barriers not a problem	Low < high	Yes	No
Crime safety	Low < high	Yes	No

[a] association with frequent walking at $p<0.1$

[b] association with occasional walking at $p<0.1$

social cohesion or civic engagement could influence perceptions of neighborhoods such as sense of safety. Key perceived attributes identified in this study (esthetics, traffic, crime) could be addressed with or without direct actions on actual environments. Local government's initiatives on landscaping, maintenance, traffic calming, and natural surveillance could assist to enhance residents' perceptions of their local area.

In this study, residential density was associated with recreational walking only in low SES areas. Low-density disadvantaged areas could include industrial areas that may not be suitable for recreational walking. In contrast, low-density high SES neighborhoods could include residential suburbs that are likely to have many places to walk. Such influences could potentially explain the association of residential density with walking in low SES areas. Objective environmental measures (intersection density, land use mix, and net retail area ratio) were not associated with walking for recreation. These findings are not surprising, as these particular walkability measures were originally developed as potential correlates of active transport.[24] It was found that low SES areas had higher scores for intersection density and land use mix that are known to be associated with walking for transport.[32,33] Increasing recreational walking may not be feasible in some low SES areas. Promoting walking for transport may be an alternative approach in such areas to address the health gap between SES areas.[34]

Residents' perceptions of walking infrastructure were associated with recreational walking only in high SES areas. The finding suggests that facilities such as footpaths, parks/nature reserves, bicycle/walking trails, traffic slowing devices, and pedestrian crossing may not be relevant to recreational walking in low SES areas. However, studies have shown associations between recreational walking with footpaths, parks, walking trails, and pedestrian crossing.[35–37] It is possible that what matters to walking is not simply the presence of these facilities, but the quality of them (quality was assessed only for footpaths in our subscale). It has been shown that the quality of parks and open spaces (the number of amenities and facilities) and that of footpaths are poorer in low SES areas.[30,38] Future research needs to examine how the quality of walking infrastructure is involved in the disparity of recreational walking between advantaged and disadvantaged areas.

This study has several limitations. Walking was self-reported, thus may be subject to recall error. Walking was also assessed without consideration of where it took place. Some recreational walking could have occurred outside the local areas for which environmental attributes were measured. The study did not measure additional potentially relevant variables, such as attitudes toward walking and preference for local areas, which could have a bearing on walking behavior and perceptions of local areas. Our findings specific to urban Adelaide, Australia, may not be generalizable to other regions, cities, or countries. Strengths of the study include a sample size large enough to conduct stratified analyses and examination of both objectively measured and perceived environmental attributes.

In conclusion, this study found that several specific environmental attributes were associated with recreational walking and that the associations were largely consistent across SES areas. However, low SES areas were disadvantaged in most attributes related to recreational walking. In particular, residents of low SES areas had lower perceptions in neighborhood esthetics, traffic/barriers, and safety from crime, which were all associated with walking for recreation. Environmental and policy interventions tailored to improve these attributes in low SES areas may help reduce the socioeconomic gap in recreational physical activity.

ACKNOWLEDGMENTS

The Spatial Epidemiology and Evaluation Research Group at the University of South Australia in collaboration with the South Australian Department of Health and Ageing conducted the Place and Metabolic Syndrome (PAMS) project under National Health and Medical Research Council (NHMRC) Project Grants (#631917, #570150). Catherine Paquet was funded by NHMRC Post-doctoral Training Research Fellowship (#570139). This manuscript has been reviewed for scientific content and consistency of data interpretation by Chief Investigators of the North West Adelaide Health Study. The authors are grateful for the interest and commitment of cohort participants, as well as the contributions of research support staff involved in recruitment and data collection.

REFERENCES

1. Kavanagh AM, Goller JL, King T, Jolley D, Crawford D, Turrell G. Urban area disadvantage and physical activity: a multilevel study in Melbourne, Australia. *J Epidemiol Community Health*. 2005; 59: 934–940.
2. Turrell G, Haynes M, Burton NW, et al. Neighborhood disadvantage and physical activity: baseline results from the HABITAT multilevel longitudinal study. *Ann Epidemiol*. 2010; 20: 171–181.
3. van Lenthe FJ, Brug J, Mackenbach JP. Neighbourhood inequalities in physical inactivity: the role of neighbourhood attractiveness, proximity to local facilities and safety in the Netherlands. *Soc Sci Med*. 2005; 60: 763–775.
4. Janssen E, Sugiyama T, Winkler E, de Vries H, te Poel F, Owen N. Psychosocial correlates of leisure-time walking among Australian adults of lower and higher socio-economic status. *Health Educ Res*. 2010; 25: 316–324.
5. National Preventative Health Taskforce. *Australia: the healthiest country by 2020—National Preventative Health Strategy—the roadmap for action*. Canberra: Commonwealth of Australia; 2009.
6. Lee IM, Buchner DM. The importance of walking to public health. *Med Sci Sports Exerc*. 2008; 40: S512–S518.
7. Sallis JF, Saelens BE, Frank LD, et al. Neighborhood built environment and income: examining multiple health outcomes. *Soc Sci Med*. 2009; 68: 1285–1293.
8. Sundquist K, Eriksson U, Kawakami N, Skog L, Ohlsson H, Arvidsson D. Neighborhood walkability, physical activity, and walking behavior: the Swedish Neighborhood and Physical Activity (SNAP) study. *Soc Sci Med*. 2011; 72: 1266–1273.
9. Van Dyck D, Cardon G, Deforche B, Sallis JF, Owen N, De Bourdeaudhuij I. Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. *Prev Med*. 2010; 50: S74–S79.
10. Blacksher E, Lovasi GS. Place-focused physical activity research, human agency, and social justice in public health: taking agency seriously in studies of the built environment. *Health Place*. 2012; 18: 172–179.
11. Inoue S, Ohya Y, Odagiri Y, et al. Association between perceived neighborhood environment and walking among adults in 4 cities in Japan. *J Epidemiol*. 2010; 20: 277–286.
12. Saelens BE, Sallis JF, Frank LD, et al. Neighborhood environment and psychosocial correlates of adults' physical activity. *Med Sci Sports Exerc*. 2012; 44: 637–646.
13. Sugiyama T, Leslie E, Giles-Corti B, Owen N. Physical activity for recreation or exercise on neighbourhood streets: associations with perceived environmental attributes. *Health Place*. 2009; 15: 1058–1063.

14. Evenson KR, Block R, Roux AVD, McGinn AP, Wen F, Rodriguez DA. Associations of adult physical activity with perceived safety and police-recorded crime: the Multi-ethnic Study of Atherosclerosis. *Int J Behav Nutr Phys Act*. 2012; 9: 146.
15. Foster S, Giles-Corti B. Does fear of crime discourage walkers? A social-ecological exploration of fear as a deterrent to walking. *Environ Behav*. 2014; 46: 698–717.
16. Arvidsson D, Kawakami N, Ohlsson H, Sundquist K. Physical activity and concordance between objective and perceived walkability. *Med Sci Sports Exerc*. 2012; 44: 280–287.
17. Ball K, Jeffery RW, Crawford DA, Roberts RJ, Salmon J, Timperio AF. Mismatch between perceived and objective measures of physical activity environments. *Prev Med*. 2008; 47: 294–298.
18. Gebel K, Bauman A, Owen N. Correlates of non-concordance between perceived and objective measures of walkability. *Ann Behav Med*. 2009; 37: 228–238.
19. Grant JF, Taylor AW, Ruffin RE, et al. Cohort profile: the North West Adelaide Health Study (NWAHS). *Int J Epidemiol*. 2009; 38: 1479–1486.
20. Australian Bureau of Statistics. *National Health Survey: users' guide—electronic publication, 2004–05*. Canberra: ABS; 2006.
21. Rzewnicki R, Vanden Auweele Y, De Bourdeaudhuij I. Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample. *Public Health Nutr*. 2003; 6: 299–305.
22. Gauvin L, Richard L, Kestens Y, et al. Living in a well-serviced urban area is associated with maintenance of frequent walking among seniors in the VoisiNuAge study. *J Gerontol B-Psychol*. 2012; 67: 76–88.
23. Mason P, Kearns A, Livingston M. "Safe Going": the influence of crime rates and perceived crime and safety on walking in deprived neighbourhoods. *Soc Sci Med*. 2013; 91: 15–24.
24. Frank LD, Sallis JF, Saelens BE, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. *Br J Sports Med*. 2010; 44: 924–933.
25. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. *Am J Public Health*. 2003; 93: 1552–1558.
26. Baldock K, Paquet C, Howard N, et al. Associations between resident perceptions of the local residential environment and metabolic syndrome. *J Environ Publ Health*. 2012; 2012: 589409.
27. Australian Bureau of Statistics. *Socio-Economic Indexes for Areas (SEIFA)—technical paper 2006*. Canberra: ABS; 2008.
28. Whisman MA, McClelland GH. Designing, testing, and interpreting interactions and moderator effects in family research. *J Fam Psychol*. 2005; 19: 111–120.
29. Saelens BE, Handy SL. Built environment correlates of walking: a review. *Med Sci Sports Exerc*. 2008; 40: S550–S566.
30. 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: 267–274.
31. Sallis JF, Slymen DJ, Conway TL, et al. Income disparities in perceived neighborhood built and social environment attributes. *Health Place*. 2011; 17: 1274–1283.
32. Duncan MJ, Winkler E, Sugiyama T, et al. Relationships of land use mix with walking for transport: do land uses and geographical scale matter? *J Urban Health*. 2010; 87: 782–795.
33. Marshall WE, Garrick NW. Effect of street network design on walking and biking. *Transp Res Rec*. 2010; 2198: 103–115.
34. Turrell G, Haynes M, Wilson L, Giles-Corti B. Can the built environment reduce health inequalities? A study of neighbourhood socioeconomic disadvantage and walking for transport. *Health Place*. 2013; 19: 89–98.
35. Cerin E, Sit CHP, Barnett A, Cheung M-C, Chan W-M. Walking for recreation and perceptions of the neighborhood environment in older Chinese urban dwellers. *J Urban Health*. 2013; 90: 56–66.

36. Starnes HA, Troped PJ, Klenosky DB, Doehring AM. Trails and physical activity: a review. *J Phys Act Health*. 2011; 8: 1160–1174.
37. Sugiyama T, Francis J, Middleton NJ, Owen N, Giles-Corti B. Associations between recreational walking and attractiveness, size, and proximity of neighborhood open spaces. *Am J Public Health*. 2010; 100: 1752–1757.
38. Crawford D, Timperio A, Giles-Corti B, et al. Do features of public open spaces vary according to neighbourhood socio-economic status? *Health Place*. 2008; 14: 889–893.