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Perceived neighbourhood environmental attributes associated with adults' recreational walking: IPEN Adult study in 12 countries

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Abstract

This study examined the strength and shape of associations between perceived environmental attributes and adults' recreational walking, using data collected from 13,745 adult participants in 12 countries. Perceived residential density, land use mix, street connectivity, aesthetics, safety from crime, and proximity to parks were linearly associated with recreational walking, while

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curvilinear associations were found for residential density, land use mix, and aesthetics. The observed associations were consistent across countries, except for aesthetics. Using data collected from environmentally diverse countries, this study confirmed findings from prior single-country studies. Present findings suggest that similar environmental attributes are associated with recreational walking internationally.

Keywords

physical activity; exercise; leisure; built environment; urban design

BACKGROUND

Participation in regular, moderate-intensity physical activity confers significant health benefits (Garber et al., 2011; Lee et al., 2012). However, the majority of adults do not meet physical activity recommendations (Australian Bureau of Statistics, 2012; Hallal, et al., 2012; National Health Service, 2009; Troiano et al., 2008). An increasing number of studies have examined associations of neighbourhood environmental attributes with physical activity (e.g., walking for recreation and for transport), and the findings have been synthesized in review papers (Ding and Gebel, 2012; Owen et al., 2004; Saelens and Handy, 2008; Sugiyama et al., 2012). To date, most studies on this topic have examined data collected in a single country, except for a few multi-country studies (De Bourdeaudhuij et al., 2005; Sallis et al., 2009; Van Dyck et al., 2013). It is possible that non-significant or weak associations reported in single-country studies may be due partly to limited variation in environmental attributes. Multi-country studies can fill this methodological gap, as countries often have different systems and regulations in developing and managing the built environment. Studies involving diverse countries thus can provide larger variance in environmental attributes that can better explain dose-response relationships between environment and physical activity. In addition, the majority of existing studies were conducted in high-income countries, particularly North America, Western Europe, and Australasia. Examining data from regions where little research has been undertaken (Asia, Eastern Europe, Latin America, Africa) is important to determine if evidence published to date is broadly generalisable. Multi-country studies are thus warranted to inform national and regional policies on how the built environment might be able to facilitate greater population-wide physical activity.

The International Physical Activity and the Environment Network (IPEN) Adult project was designed to examine associations of neighbourhood environment with physical activity across 12 environmentally- and culturally-diverse countries (Kerr et al., 2013). Within the IPEN Adult project, the present study focused on associations of recreational walking with participants’ perceptions of their neighbourhood environment. Walking is often the major focus of physical activity promotion initiatives for adults, because it is the most common activity, has well-documented health benefits, and is acceptable for a large proportion of the population (Lee and Buchner, 2008; Murtagh et al., 2010). Environmental perceptions play an important role in the relationship between physical activity and the environment because how people perceive and interpret their surroundings can affect their physical activity patterns (Blacksher and Lovasi, 2012). The significance of perceptions is further demonstrated by the fact that residents' perceptions of their neighbourhoods do not always agree with objectively-measured environmental characteristics (Adams et al., 2009; Gebel et al., 2011), and perceptual measures can assess potentially important aspects such as aesthetics and sense of safety that are difficult to measure objectively.

The present paper examined the strength and shape of associations of perceived neighbourhood environmental attributes with adults' recreational walking using data obtained from 12 countries, and whether these associations differed across countries.

METHODS

Procedure and participants

The IPEN Adult project was an observational, epidemiologic, multi-country, cross-sectional study. A detailed description of the methods is reported elsewhere (Kerr et al., 2013). Briefly, 13,745 adults aged between 18 and 66 years from 12 countries (17 study sites) participated. Countries included Australia (abbreviation: AUS; study site: Adelaide), Belgium (BEL; Ghent), Brazil (BRZ; Curitiba), Colombia (COL; Bogota), the Czech Republic (CZ; Olomouc, Hradec Kralove), Denmark (DEN; Aarhus), Hong Kong (HK), Mexico (MEX; Cuernavaca), New Zealand (NZ; North Shore, Waitakere, Wellington, Christchurch), Spain (ESP; Pamplona), the United Kingdom (UK; Stoke-on-Trent), and the United States of America (USA; Seattle, Baltimore). In each study site, neighbourhoods were chosen to maximise the variance in environmental attributes potentially related to physical activity and socio-economic status (SES). In all countries except Spain, a neighbourhood walkability index was determined for the whole study region using GIS data derived from the smallest administrative units available (Frank et al., 2010), and neighbourhoods were ranked in terms of the index. In Spain, neighbourhood selection was based on neighbourhood construction date, which is an indicator of walkability (Berrigan and Troiano, 2002). For area-level SES, most countries used median household income or deprivation index, except for New Zealand, where the proportion of indigenous population was used as an indicator. Then, an equal number of neighbourhoods were selected from each of four categories: high walkable/high SES, high walkable/low SES, low walkable/high SES, and low walkable/low SES. The number of participating neighbourhoods ranged from 16 in Denmark and the UK to 62 in the Czech Republic.

Households or individuals in the chosen neighbourhoods were identified using databases of residential addresses from commercial and government sources. In all countries but Hong Kong (where participants were recruited from quasi-randomly-selected buildings located in pre-selected administrative units), households were randomly selected, and an adult resident (identified from the database source or an adult in the household with the most recent birthday) was invited to participate. About half the countries employed telephone and postal surveys to collect data, and half conducted household interviews in person. In Hong Kong, intercept interviews were conducted in residential areas where individual addresses were not available (e.g., in large apartment buildings with security restrictions, where individual unit numbers were unavailable). Sample sizes per site ranged from 167 (Hradec Kralove, the Czech Republic) to 2650 (Australia). The study was conducted between 2007 and 2011, except for the USA (2002–2005) and Australian sites (2003–2004). Each country obtained ethical approval from their local institutions as well as San Diego State University, and all participants provided written informed consent.

Measures and Instruments

Physical Activity—Self-reported physical activity was assessed with the International Physical Activity Questionnaire (IPAQ; long version). The IPAQ was evaluated in 12 countries on five continents and found to have good test-retest reliability (ICC=0.46–0.96) and fair-to-moderate criterion validity (median ρ=0.30) compared against accelerometer measures (Craig et al., 2003). Participants reported the number of days they walked for recreation (at least 10 minutes at a time) in the last seven days and the average duration of walking on one of those days. The frequency (days/week) and duration (minutes/week) of walking for recreation were the outcome variables.

Environmental Perceptions—The Neighborhood Environment Walkability Scale (NEWS; Saelens et al., 2003) or NEWS-Abbreviated (Cerin et al., 2007) was used to gather perceived neighbourhood data. Confirmatory factor analysis has been conducted for the items to create subscales that maximised cross-country comparability of responses across the 12 IPEN countries. The following nine scales were identified: residential density; land use mix–access; street connectivity; infrastructure and safety; aesthetics; safety from traffic; safety from crime; few cul-de-sacs; and no major barriers (Cerin et al., 2013). The land use mix–diversity scale was omitted because it was highly correlated with land use mix–access. All items were rated on a scale ranging from 1 (strongly disagree) to 4 (strongly agree), except for residential density, where participants' response to the presence of various types of housing in neighbourhoods was scored using a density-weighting formula shown elsewhere (Cerin et al., 2013). Studies conducted in several countries reported high test-retest reliability scores (ICC > 0.75) for most scales (Cerin et al., 2007; De Bourdeaudhuij, et al., 2003; Leslie et al., 2005; Saelens et al., 2003; Oyeyemi et al., 2013). A single-item attribute of 'distance to the nearest park' was also included. The response format for this item ranged from 1 (more than 30 min walking distance) to 5 (1–5 minute walking distance). All measures examined here were scored such that higher values were expected to be positively related to recreational walking.

Covariates—Individual-level covariates were self-reported socio-demographic variables including age, gender, education (less than high school; high school diploma; college or university degree), work status (not working; working) and marital status (living with partner or not). Area-level SES (low versus high based on the design procedures for neighbourhood selection) was also included as a covariate.

Data analytic plan

Descriptive statistics (means, medians, standard deviations, percentages, and percentages of missing values) were computed, as appropriate, by study site for all relevant variables. Over 7% of cases had missing data on at least one of the examined variables. The presence of missing data on specific variables was related to other variables included in the study, i.e., data were at least missing at random (MAR) rather than missing completely at random

(MCAR), indicating that the likelihood of missingness is unrelated to measured or unmeasured variables (Rubin, 1987). Consequently, ten imputed datasets were created for the main regression analyses (see below) as recommended by Rubin (1987) and van Buuren (2012). Analyses based on complete data only when missing data are MAR can yield biased results, while analyses based on properly-conducted multiple imputations do not (Rubin, 1987). Multiple imputations were performed using chained equations (MICE; van Buuren, 2012) accounting for within-site administrative-unit-level cluster effects arising from the two-stage stratified sampling strategy employed in each study site (see Methods section). The ten imputed datasets were created in R (R Core Team, 2013) using the package 'mice' and following the model-building and diagnostic procedures outlined by van Buuren (2012).

Analyses estimated the strength and shape of associations of perceived environmental attributes with weekly frequency and duration of recreational walking for the whole sample, and whether these associations varied by study sites. For this purpose, generalized additive mixed models (GAMMs) were used (Wood, 2006). GAMMs can model data following various distributional assumptions (e.g., positively-skewed physical activity data), account for dependency in error terms due to clustering (observations sampled from selected administrative units), and estimate complex, dose-response relationships of unknown form (Wood, 2006). Preliminary analyses indicated that the frequency and duration of walking followed a zero-inflated negative binomial distribution, i.e., a negative binomial distribution with a larger number of zeros (no walking for recreation in the past week) than assumed by the distribution. Given that current GAMMs packages do not encompass zero-inflated regression models, separate GAMMs were estimated to identify perceived environmental attributes associated with (1) likelihood of any walking for recreation versus no walking for recreation; (2) frequency (days/week) of walking for recreation among the subgroup reporting walking during the past week; and (3) duration (minutes/week) of walking for recreation among the subgroup reporting walking during the past week. The GAMM of any walking for recreation provided information on possible perceived environmental correlates determining the decision of being a recreational walker, while the other two GAMMs provided information on potential environmental correlates of the frequency and amount of walking in recreational walkers. The first set of GAMMs used binomial variance and logit link functions. The reported antilogarithms of the regression coefficient estimates of these models represent odds ratios of walking versus not walking. The other two GAMMs used negative binomial and logarithmic link functions. The reported antilogarithms of the regression coefficient estimates of these two GAMMs represent the proportional increase in frequency or duration of walking for recreation associated with a unit increase in the predictor.

A main-effect set of GAMMs estimated the dose-response relationships of all perceived environmental attributes theoretically relevant to walking for recreation (seven scales and three single items) with the three walking outcomes discussed above, adjusting for study site, socio-demographic covariates, and the administrative unit level SES. It was justified to simultaneously enter all variables in the GAMMs as they were not collinear (mean absolute correlation = 0.15; maximum absolute correlation = 0.33). Curvilinear relationships of environmental attributes with outcomes were estimated using non-parametric smooth terms in GAMMs, which were modelled using thin-plate splines (Wood, 2006). Smooth terms failing to provide evidence of a curvilinear relationship (based on Quasi Akaike's Information Criterion; QAIC) were replaced by simpler linear terms. Separate GAMMs were run to estimate environmental attributes by study site interaction effects. The significance of interaction effects was evaluated by comparing QAIC values of models with and without a specific interaction term, whereby the model with the smaller QAIC was preferred. Significant interaction effects were probed by computing the site-specific association of a perceived environmental attributed with the relevant outcome via linear functions. All analyses were conducted in R (R Core Team, 2013) using the packages ‘car’ (Fox and Weisberg, 2011), ‘mgcv’ (Wood, 2006), ‘gmodels’ (Warnes, 2012), and ‘mice’ (van Buuren and Groothuis-Oudshoorn, 2011).

RESULTS

Sample characteristics and descriptive information of walking and environmental attributes

The total sample consisted of 13,745 participants; 57% were women, 44% had a college or university degree, 75% were working, and 60% were married or living with a partner. The mean age was 42 years. Table 1 reports the descriptive statistics for the whole sample and for each study site, including socio-demographic characteristics, frequency and duration of recreational walking (including and excluding non-walkers), and percentage of respondents reporting no walking for recreation in the last week. Overall, participants walked for recreation about two days a week for an average duration of slightly less than 2 hours/week, although more than 40% reported no walking for recreation. Mean walking frequency ranged from around one day/week in Belgium, Brazil, Colombia, and Mexico to more than 2.5 days/week in the Czech Republic, Denmark, and Spain. The duration of recreational walking was lower in Latin America (Mexico, Colombia, and Brazil; about 1 hour/week) followed by New Zealand, and higher in European countries (the Czech Republic, Denmark, and Spain; more than 3 hours/week). Australia, Hong Kong, the UK, and the USA were in the middle in terms of the walking measures.

Table 2 shows the mean perceived environmental scores. Participating countries were diverse in perceived residential density: it ranged from around 20 in two sites in New Zealand to 440 in Hong Kong, where the score was more than two times higher than the second highest country (Spain). Larger between-site variability was also found for perceived safety from crime (from 2.1 in Colombia to 3.5 in Spain), no major barriers (from 2.2 in Hong Kong to 3.7 in Australia, Demark, and one USA site), and proximity to parks (from 3.1 in Belgium to 4.8 in Spain). Between-site variability was relatively smaller in land use mix–access, connectivity, infrastructure and safety, safety from traffic, and few cul-de-sacs. It was notable that perceived safety from crime was lower in Latin American countries and Hong Kong compared with European countries and the USA. Spain had the highest scores on five out of 10 perceived environmental characteristics that were hypothesised to be relevant to walking for recreation.

Dose-response relationships between perceived environmental attributes and recreational walking

As shown in Model 1 in Table 3, the logits of walking for recreation were linearly positively related to perceived aesthetics, perceived safety from crime, and proximity to parks; negatively related with having few cul-de-sacs in the neighbourhood; and curvilinearly related to perceived residential density and land use mix–access. One unit increase on the 4-point scale of perceived aesthetics, for example, was associated with a 26% increase in the odds of walking for recreation, while one unit increase in perceived proximity to parks (on the scale from 1 to 5) was predictive of a 7% increase in the odds of walking. The curvilinear associations of perceived residential density and land use mix–access with the odds of walking are depicted in Figure 1. An inverted-U shape relationship was observed for residential density score, although the level of uncertainty (95% confidence intervals) at the upper end of the scale was high. Greater perceived residential density was predictive of higher odds of walking, up to a score of approximately 300, with lower odds of walking thereafter. The relationship between the odds of walking and land use mix–access was somewhat J-shaped, with clear increases in the odds of walking starting from a score of 2.5 on a 4-point scale. No significant perceived environmental attributes by study site interaction effects were observed on the odds of walking for recreation, indicating that the observed associations applied to all study sites.

Among participants who reported walking for recreation, the (non-zero) frequency of walking for recreation was positively linearly associated with perceived street connectivity and aesthetics (Table 3, Model 2). Among those who walked for recreation, well-connected streets and better aesthetics were associated with a higher frequency of walking. No significant interactions between perceived environmental attributes and study sites were observed for walking frequency. Among participants reporting some recreation walking during the past week, GAMMs provided support for a linear positive relationship of non-zero duration of walking for recreation with perceived residential density and land use mix–access (Table 3, Model 3). Those perceiving higher residential density and mixed land use were more likely to walk longer. Perceived aesthetics was curvilinearly related to duration of recreational walking (among walkers), with scores above 2.3 (on a scale from 1 to 4) being positively associated with duration of walking, and scores below 2.3 having relatively little impact on walking duration (Figure 2). Study site moderated the association of perceived aesthetics with walking duration. Table 4 shows site-specific analyses, indicating significant, positive associations only in Hong Kong, New Zealand (Site C, D), and the USA (Site H).

DISCUSSION

This large-scale multi-country study examined whether perceived neighbourhood environmental attributes were associated with recreational walking. Out of the 10 perceived environmental attributes examined, seven were (either linearly or curvilinearly) positively associated with at least one of three walking outcomes. People's perceptions of these seven environmental attributes (residential density; land use mix; connectivity; aesthetics; safety from crime; few cul-de-sacs; proximity to parks) appear to be related to their recreational walking behaviour (walk or not, how often, and how long). Three environmental attributes (infrastructure and safety; safety from traffic; no major barriers) were not associated with any of the walking measures. Recreational walking may be independent of how people perceive these environmental characteristics.

An environmental attribute that had an informative set of relationships with recreational walking was neighbourhood aesthetics. It was significantly associated with all three walking measures (linearly with the odds and frequency of walking, and curvilinearly with the amount of walking). The significance of aesthetics in recreational walking has been identified in other studies (Owen et al., 2004; Saelens and Handy, 2008; Sugiyama et al., 2012) and was shown to have broad international relevance in the present study. We found that aesthetics had the largest effect size on the odds of walking, and on walking frequency: one unit increase in aesthetics (on the scale of 1 to 4) was associated with a 26% higher likelihood of walking and with a 5% higher walking frequency. There was a curvilinear association between walking duration and aesthetics. Lower aesthetics scores were not associated with walking duration (i.e., duration of walking for recreation did not increase within increasing perceived aesthetics) in aesthetically poor neighbourhoods, but better aesthetics in the mid-to-high range of the scale seems to contribute to longer recreational walking. However, it was also found that the associations of aesthetics with duration of walking varied between study sites. The site-specific analyses revealed that aesthetics was not linearly related to duration of walking in three quarters of the study sites (13 out of 17). This is in contrast to the results that aesthetics was most strongly associated with the odds and frequency of walking. Further research is needed to identify reasons for site-specific results for walking duration. Perhaps, there are moderators of the aesthetics-walking duration association. The ability to detect associations within countries may be limited by smaller sample sizes and less variation in both the independent and dependent variables. Nonetheless, the linear association with the odds and frequency of walking and the curvilinear association with walking duration were consistent across the study sites. The findings appear plausible, considering the discretionary nature of recreational walking. A review of qualitative studies on park use, for which walking may be a common activity, shows the importance of aesthetic dimensions such as attractiveness, vegetation, maintenance, and cleanliness (McCormack et al., 2010). Having aesthetically-pleasing places to walk nearby can be a strong incentive to do recreational walking. The implication of these findings is that making neighbourhoods pleasant to walk in by means of urban design, natural features such as vegetation and water, and maintenance may attract residents to walk more often for recreation as well as longer when aesthetics is in the mid-to-high range.

Those who perceived their neighbourhood as unsafe to walk due to crime were less likely to walk for recreation. However, review papers have shown safety from crime to be mostly unrelated to recreational walking (Foster and Giles-Corti, 2008; Saelens and Handy, 2008; Sugiyama et al., 2012; Van Holle et al., 2012). Recent single-country studies reported mixed findings on this topic. Studies in Brazil (Gomes et al., 2011), Japan (Inoue et al., 2011), and The Netherlands (Kramer et al., 2013) showed no association of safety from crime with walking for recreation, but results from Nigeria (Oyeyemi et al., 2012) and the USA (Evenson et al., 2012) supported an interpretation that crime is an important correlate of physical activity. It is possible that the present study was able to identify a significant association because data were gathered from diverse countries, thus expanding the range of variation. How people perceive crime and the extent to which such perceptions influence walking may be different in different locations (Rech et al., 2012). Future research on safety from crime and physical activity may need to examine both objective crime data and people's perceptions in multiple countries.

The findings obtained for cul-de-sacs and street connectivity were complex. On one hand, participants living in areas with many cul-de-sacs (i.e., low street connectivity) were more likely to walk for recreation. On the other hand, higher street connectivity was positively associated with the frequency of walking (among those who walked for recreation). The current analyses do not provide sufficient information to disentangle these findings. However, it is possible that each of these two street-related attributes may be a surrogate for different aspects of environments that are associated with walking. Cul-de-sacs may be an indicator of aesthetically pleasing environments or suburbs with better access to recreational opportunities, while areas with a grid street pattern may have more non-residential destinations that make walking more interesting. High street connectivity is known to be related to walking for transport rather than to walking for recreation (Saelens and Handy, 2008; Sugiyama et al., 2012). Well-connected street networks may facilitate residents' walking for transportation by providing direct and short routes to destinations (Berrigan et al., 2010). However, such 'directness' is unlikely to be a relevant decision factor for recreational walking. It is possible that street connectivity may involve multiple environmental constructs (e.g., more route options, access to facilities for walking, aesthetics) that may be differently associated with recreational walking. Further research examining mechanisms through which different street patterns encourage or discourage recreational walking is needed.

Proximity to parks emerged as a significant correlate of doing any recreational walking. Studies conducted in Australia suggested that park size and quality aspects rather than proximity were more relevant to recreational walking (Cleland et al., 2008; Giles-Corti et al., 2005; McCormack et al., 2008; Sugiyama et al., 2010). The measure used for park proximity in the present study was a single item, simply focusing on the distance to the nearest park. Proximity to parks may be an important factor in recreational walking in countries with limited physical activity infrastructure. Compared to 'structural' elements of a neighbourhood such as land use and street layout, parks are potentially more amenable to change. Examining additional aspects of neighbourhood parks (e.g., facilities, amenities, and maintenance) that can contribute to residents' walking is an important future research topic.

Residential density and land use mix were curvilinearly associated with walking for recreation. As shown in Figure 1, the odds of walking for recreation increased up to the optimum point where the density score was about 300, then walking declined as residential density score further increased. However, the highest mean residential density score excluding Hong Kong (440), which is a unique environment, was 200 for Spain. Thus, it is reasonable to argue that within typical urban settings, perceived residential density is positively associated with recreational walking. However, in extremely dense areas such as Hong Kong, higher density may cause lack of opportunities for physical activity or introduce barriers such as pedestrian congestion, which may discourage residents from walking for recreation. For land use mix–access, which measured access to shops, services, and transit stops, the odds of walking were the lowest around the score of 2.5, and then they increased with higher levels of perceived access. The destinations used to assess land use mix (shops, services, transit stops) were not necessarily relevant to recreational walking. However, having many non-residential destinations may be a factor involved in residents' decision to walk for recreation. Residential density and land use mix were also associated linearly with the amount of walking. People living in neighbourhoods with higher residential density and easily-accessible destinations tended to walk longer for recreation. Urban settlements that help residents to be active for transportation may also facilitate their walking for recreation.

There were no statistically-significant associations of recreational walking with pedestrian infrastructure and safety, safety from traffic, and lack of major barriers to walking. The construct of infrastructure and safety was mainly about sidewalks (availability and separation from traffic). It is surprising that pedestrian infrastructure was not related to walking for recreation, because sidewalks can be considered an essential facility for safe walking. In a previous international study, presence of sidewalks had the strongest association with physical activity of any single variable (Sallis et al., 2009). However, the scale score in the present study was relatively stable across countries (means ranging from 2.6 to 3.3), which may have contributed to the non-significant findings. Walking/cycling paths (trails, greenways) may be important resources for recreational walking (Fitzhugh et al., 2010), but such facilities were not included in the present study. The finding of no association between safety from traffic and recreational walking is consistent with previous studies (Saelens and Handy, 2008; Sugiyama et al., 2012). A recent study in the Netherlands found traffic safety to be associated with recreational cycling but not with recreational walking (Kramer et al., 2013). It is possible that traffic safety is a construct consisting of several dimensions, such as traffic volume, speed, and facilities for protecting and separating pedestrians and cyclists from traffic. Research needs to examine how more specific aspects of traffic safety are related to walking for recreation. Perceived barriers to walking were also unrelated to the walking outcomes. Walking for recreation is a discretionary activity. Even if participants recognise barriers, they may be able to find ways to circumvent them by taking a different route. Another possibility is that the specific barriers identified, such as highways or steep hills, were not common enough to yield a detectable association.

The study found some between-country differences both in the walking measures and environmental perceptions. Overall, participants in some European countries (the Czech Republic, Denmark, and Spain) tended to walk more often and longer for recreation, and to report better environmental perceptions. In contrast, Latin American countries (Brazil, Colombia, and Mexico) were lower in the walking frequency, duration, and some environmental attributes. Combining data from such diverse countries (both in walking behaviours and environmental attributes) is a merit of this study, as it can help identify relevant environmental attributes that may not be detectable in a single-country study.

A strength of the present study was that it was a large-sample, multi-country study, conducted using standardised data collection methods and validated measures. The study also employed advanced analytical methods, which allowed us to examine not only the strength of associations, but also the shape of associations. Study limitations included use of self-report measures of walking and environmental attributes, which involve reporting bias and recall error. The criterion validity of IPAQ-derived total physical activity (rank-order correlation with accelerometer) varies across countries (Craig et al., 2003), but the reasons for variations in validity have not been determined. It is possible that participants in different countries responded differently to the walking questions. However, given that there is currently no objective measure to identify domain-specific walking, research needs to rely on self-report behavioural measures. Although objective environmental measures are important in informing policy and practice in urban planning and transport, perceived environmental attributes still need to be studied, as both perceived and objective measures have been shown to be independently associated with physical activity (Evenson et al., 2012; McGinn et al., 2007). Some variables are more suitable for self-reported measures, such as aesthetics and perceptions of safety from crime, which were identified as consistent correlates of walking for recreation in the present study.

CONCLUSION

Using data collected in 12 countries, adults' walking for recreation was found to be associated with neighbourhood aesthetics, residential density, land use mix (access to destinations), safety from crime, and proximity to parks, in the expected directions. These findings confirm those from previous studies with regard to aesthetics and access to destinations. However, these analyses from the IPEN Adult study also identified some environmental attributes (safety from crime, proximity to parks) where the association with recreational walking was previously unclear. The associations observed were mostly consistent across countries, suggesting the generalisability of the findings. This is an important observation, because if built environments are similarly related to recreational walking in these 12 diverse countries, then environmental design has potential to be a public health intervention that could apply to many more countries. The main contribution of the present study was that it identified multiple environment attributes related to physical activity on an international basis. In particular, aesthetics appears to be an important factor in whether and how often people walk for recreation that applies across diverse countries. Higher population density (but not excessively high density such as in Hong Kong) and higher land use diversity seem to contribute to longer duration of recreational walking. Present results are the best evidence to date about built environment features that support walking for recreation across diverse countries. While studies further assess generalizability of observed associations across additional countries, a next step in the research is to conduct natural experiments to evaluate improvements in aesthetics, increased density, and enhanced mixed use to boost evidence for causality.

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Highlights

- We analysed data collected from 12 environmentally diverse countries.
- Adults' recreational walking was associated with several environmental perceptions.
- Aesthetics was relevant to whether and how often adults walk for recreation.
- Most associations observed were consistent across participating countries.
- Curvilinear associations of walking with environmental attributes were also found.

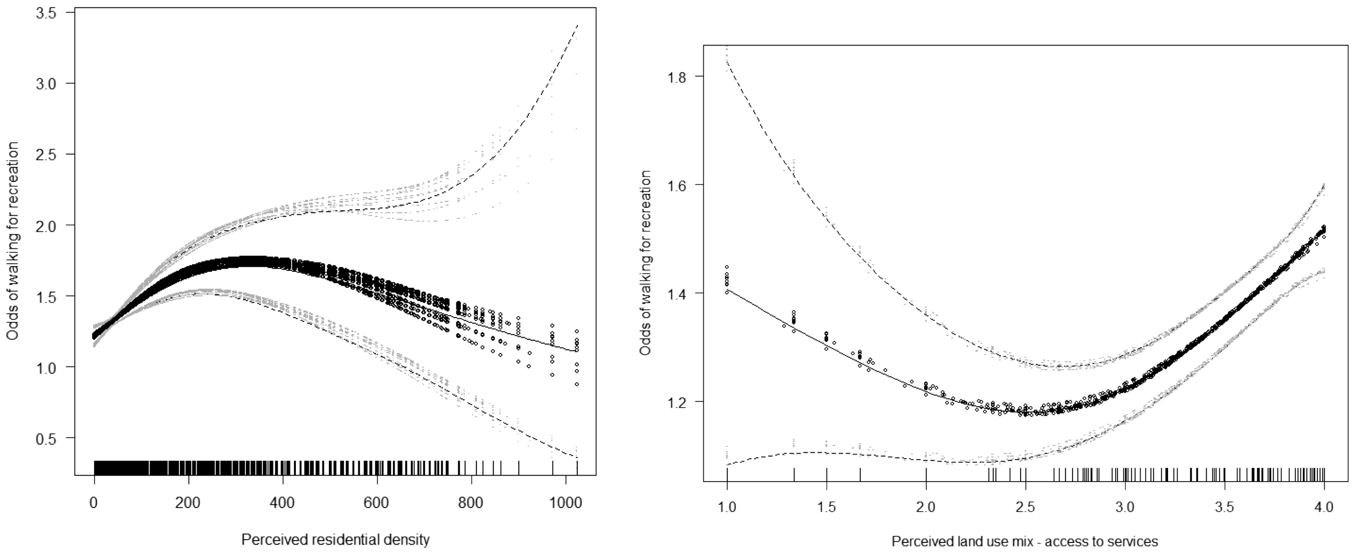

Figure 1.

Curvilinear relationship between environmenta l attributes and the odds of walking for recreation

Note. The solid line represents point estimates (and black dashed lines their 95% confidence intervals) of the odds of walking at various levels of perceived environmental attribute for the imputed dataset producing median values of odds of walking (relative to other imputed models). The black dots and grey dashed lines represent the same estimates produced by the other nine imputed datasets.

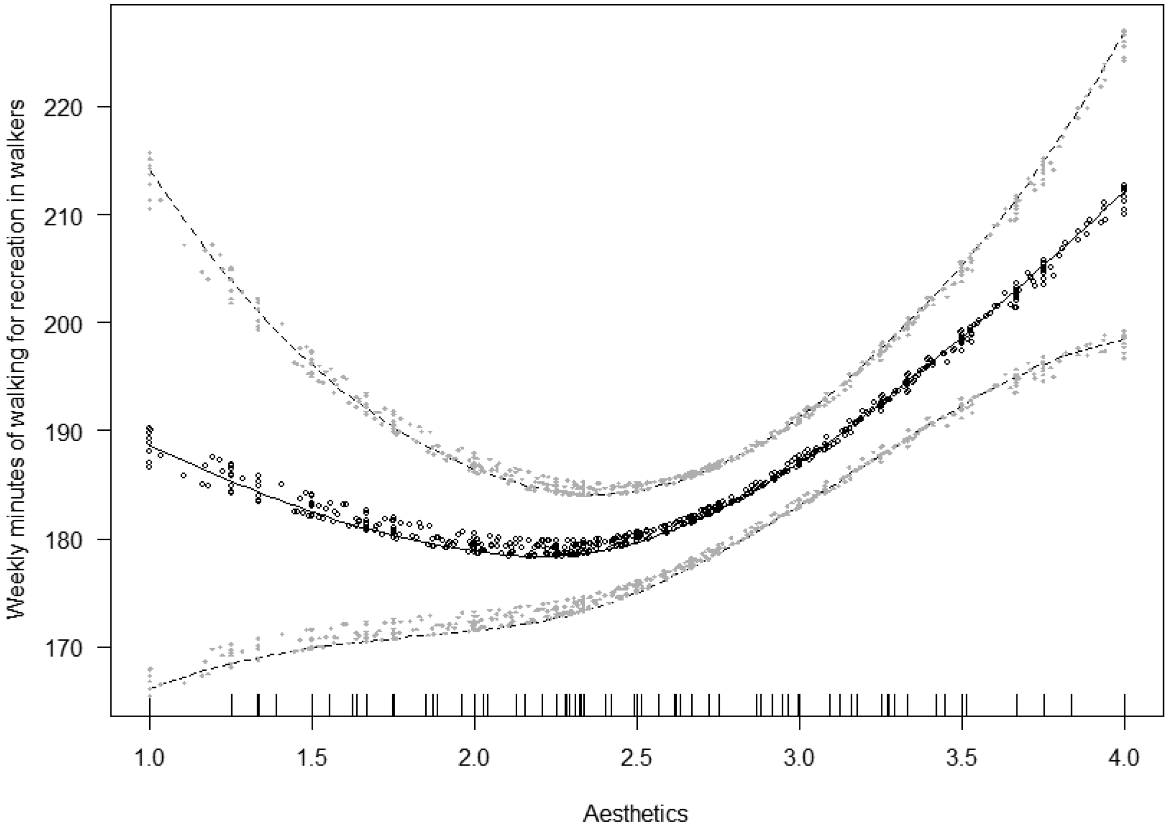

Figure 2.
Curvilinear relationship between perceived aesthetics and duration of walking for recreation among walkers
Note. The solid line represents point estimates (and dashed lines their 95% confidence intervals) of walking duration (among walkers) at various levels of perceived aesthetics for the imputed dataset producing median values of duration of walking (relative to other imputed models). The dotted lines represent the same estimates produced by the other nine imputed datasets.

Table 1

Overall and site-specific sample characteristics [% or mean (SD)]

	ALL SITES	AUS	BEL	BRA	COL	CZ		DEN	HK	MEX	NZ				ESP	UK	USA	
						Site A	Site B				Site C	Site D	Site E	Site F			Site G	Site H
Overall N[1]	13745	2650	1166	697	963	330	167	642	493	677	511	512	496	495	904	843	1287	912
Age	42 (12.8)	44 (12.3)	43 (12.6)	41 (13.2)	40 (13.7)	38 (14.7)	34 (13.1)	39 (13.9)	43 (11.7)	42 (12.6)	41 (11.8)	41 (11.8)	39 (12.6)	42 (12.6)	39 (14.2)	43 (13.3)	44 (11.0)	47 (10.7)
Gender, *%men*	43	36	48	47	36	37	40	43	41	45	36	39	49	44	45	44	55	48
Education, *%*																		
Less than HS	17	24	4	29	36	22	17	8	37	43	4	5	1	11	7	34	1	2
HS graduate	39	30	35	32	42	46	57	44	23	29	58	64	47	57	35	52	36	30
College or more	44	46	61	39	22	32	26	48	40	28	38	31	52	32	58	14	63	68
Work status, *%working*	75	71	80	78	58	77	84	75	66	72	78	84	87	80	72	64	81	83
Marital status, *%with partner*	60	57	73	58	53	58	47	65	59	65	70	74	57	55	53	45	63	60
Walking																		
Frequency[2]	1.9 (2.3)	2.0 (2.3)	1.0 (1.6)	1.2 (2.0)	1.1 (2.0)	2.7 (2.6)	2.5 (2.5)	2.8 (2.4)	2.2 (2.5)	1.2 (2.1)	1.7 (2.1)	1.8 (2.3)	2.3 (2.3)	1.5 (2.1)	3.6 (2.7)	1.6 (2.3)	2.1 (2.3)	2.0 (2.3)
Non-zero frequency[3]	3.4 (2.2)	3.3 (2.1)	2.1 (1.8)	3.1 (2.0)	3.0 (2.3)	3.9 (2.3)	3.8 (2.2)	3.6 (2.2)	3.6 (2.2)	3.5 (2.1)	3.0 (2.0)	3.3 (2.2)	3.3 (2.0)	3.1 (2.1)	4.6 (2.2)	3.4 (2.2)	3.2 (2.0)	3.3 (2.1)
Duration[4]	115 (226)	125 (233)	80 (156)	54 (112)	64 (164)	215 (330)	182 (246)	199 (308)	115 (241)	58 (174)	84 (171)	70 (108)	112 (172)	75 (124)	234 (356)	129 (268)	120 (222)	105 (173)
Non-zero duration[5]	204 (249)	207 (270)	165 (190)	146 (142)	176 (235)	316 (359)	279 (257)	253 (328)	195 (287)	170 (265)	153 (207)	127 (118)	162 (186)	155 (138)	301 (378)	279 (336)	182 (252)	170 (193)
%reporting no walking	43	39	52	63	64	32	35	21	39	64	45	45	30	52	22	53	32	38

Notes:

Site A: Olomouc, B: Hradec Kralove, C: North Shore, D: Waitakere, E: Wellington, F: Christchurch, G: Seattle, H: Baltimore

Missing values: age (1.5%), gender (0.3%), education (1.2%), work status (0.3%), marital status (1.2%), walking frequency (0.7%), walking minutes (1.1%)

[1] N for some variables is reduced due to missing data.

[2] days/week

[3] days/week among those who reported walking

[4] minutes/week

[5] minutes/week among those who reported walking

Table 2

Overall and site-specific perceived environmental scores [mean (SD)]

	ALL SITES	AUS	BEL	BRA	COL	CZ		DEN	HK	MEX	NZ				ESP	UK	USA	
						Site A	Site B				Site C	Site D	Site E	Site F			Site G	Site H
Residential density score	77 (114)	36 (41)	84 (73)	100 (123)	77 (82)	91 (70)	92 (70)	86 (65)	440 (235)	38 (41)	29 (47)	18 (26)	49 (68)	22 (25)	200 (104)	40 (41)	39 (57)	60 (79)
Land use mix–access[1]	3.4 (0.66)	3.5 (0.66)	3.3 (0.61)	3.7 (0.52)	3.4 (0.45)	3.4 (0.67)	3.4 (0.65)	3.6 (0.55)	3.2 (0.77)	3.3 (0.48)	3.2 (0.56)	3.1 (0.53)	3.4 (0.47)	3.3 (0.50)	3.7 (0.48)	3.3 (0.77)	3.2 (0.80)	3.0 (0.82)
Connectivity[1]	3.0 (0.73)	2.8 (0.93)	2.7 (0.72)	3.3 (0.69)	3.2 (0.51)	3.0 (0.67)	2.9 (0.60)	3.0 (0.61)	2.9 (0.76)	2.9 (0.51)	2.7 (0.48)	2.7 (0.44)	2.8 (0.45)	3.0 (0.47)	3.2 (0.67)	3.1 (0.66)	3.0 (0.80)	3.0 (0.78)
Infrastructure and safety[1]	3.0 (0.57)	3.0 (0.60)	2.8 (0.48)	2.8 (0.80)	2.8 (0.46)	3.1 (0.53)	3.2 (0.47)	3.1 (0.53)	3.3 (0.62)	2.6 (0.43)	2.8 (0.34)	2.8 (0.39)	2.9 (0.36)	2.9 (0.37)	3.3 (0.51)	3.1 (0.50)	3.0 (0.64)	3.1 (0.60)
Aesthetics[1]	2.8 (0.70)	2.9 (0.70)	2.5 (0.62)	2.8 (0.80)	2.5 (0.55)	2.4 (0.60)	2.5 (0.57)	2.7 (0.56)	2.7 (0.71)	2.6 (0.53)	2.8 (0.54)	2.8 (0.45)	2.8 (0.53)	2.8 (0.57)	2.8 (0.65)	2.2 (0.75)	3.1 (0.68)	3.1 (0.64)
Safety from traffic[1]	2.6 (0.67)	2.8 (0.77)	2.4 (0.62)	2.4 (0.77)	2.5 (0.53)	2.9 (0.64)	3.1 (0.51)	2.8 (0.51)	2.4 (0.63)	2.4 (0.50)	2.6 (0.48)	2.6 (0.48)	2.8 (0.44)	2.7 (0.51)	2.4 (0.66)	2.5 (0.73)	2.7 (0.72)	2.7 (0.67)
Safety from crime[1]	3.0 (0.80)	3.0 (0.77)	3.1 (0.55)	2.3 (0.48)	2.1 (0.69)	3.2 (0.57)	3.4 (0.58)	3.3 (0.60)	2.2 (1.01)	2.2 (0.65)	3.0 (0.52)	2.9 (0.43)	3.1 (0.42)	2.9 (0.60)	3.5 (0.63)	2.9 (0.75)	3.4 (0.64)	3.4 (0.69)
Few cul-de-sacs[1]	2.8 (1.00)	2.8 (1.10)	3.0 (0.78)	3.0 (1.09)	2.9 (0.78)	2.9 (0.94)	2.9 (0.87)	2.7 (0.91)	2.3 (1.15)	2.6 (0.75)	2.3 (0.66)	2.3 (0.60)	2.5 (0.67)	2.6 (0.80)	3.5 (0.93)	2.4 (0.97)	2.8 (1.12)	2.8 (1.17)
No major barriers[1]	3.3 (0.84)	3.7 (0.70)	3.3 (0.74)	3.1 (1.04)	3.0 (0.74)	3.4 (0.81)	3.5 (0.78)	3.7 (0.58)	2.2 (1.14)	2.8 (0.73)	3.3 (0.63)	3.2 (0.59)	3.3 (0.53)	3.5 (0.64)	3.6 (0.80)	3.3 (0.80)	3.2 (0.96)	3.7 (0.62)
Proximity to parks[2]	4.1 (1.2)	4.6 (0.70)	3.1 (1.54)	4.7 (0.64)	4.3 (1.02)	3.4 (1.26)	3.9 (1.26)	4.5 (0.78)	3.8 (1.29)	3.2 (1.47)	4.5 (0.92)	4.4 (1.06)	4.6 (0.68)	4.6 (0.72)	4.8 (0.56)	3.2 (1.50)	4.0 (1.16)	3.8 (1.35)

Notes:

Site A: Olomouc, B: Hradec Kralove, C: North Shore, D: Waitakere, E: Wellington, F: Christchurch, G: Seattle, H: Baltimore

Missing values: residential density score (2.5%), land use mix–access (0.7%), connectivity (0.7%), infrastructure and safety (0.5%), aesthetics (0.6%), safety from traffic (0.7%), safety from crime (0.7%), few cul-de-sacs (0.9%), no major barriers (0.8%), proximity to parks (1.0%)

[1]Ranged from 1 to 4

[2]Ranged from 1 to 5

Table 3

Linear and curvilinear associations of perceived environmental attributes with recreational walking

Perceived environmental attribute	Model 1: Odds of walking for recreation[a] (N=13745)			Model 2: Non-zero frequency (days/wk) of walking for recreation[b] (N=7838)			Model 3: Non-zero duration (minutes/wk) of walking for recreation[b] (N=7838)		
	OR	**95%CI**	**p**	**exp(b)**	**exp(95%CI)**	**p**	**exp(b)**	**exp(95%CI)**	**p**
Residential density score	1.08	0.88, 1.32	0.482	1.001	0.999, 1.003	0.138	**1.001**	**1.000, 1.001**	**0.005**
Curvilinear component	**F(2.57)=7.94**	–	**<0.001**	–	–	–	–	–	–
Land use mix–access	1.02	0.90, 1.17	0.726	1.02	0.99, 1.05	0.062	**1.07**	**1.02, 1.11**	**0.003**
Curvilinear component	**F(2.49)=8.95**	–	**<0.001**	–	–	–	–	–	–
Connectivity	1.01	0.96, 1.07	0.745	**1.02**	**1.00, 1.05**	**0.025**	1.02	0.98, 1.05	0.298
Infrastructure and safety	1.01	0.94, 1.09	0.826	0.97	0.94, 1.00	0.053	0.98	0.92, 1.04	0.519
Aesthetics	**1.26**	**1.18, 1.35**	**<0.001**	**1.05**	**1.03, 1.08**	**<0.001**	1.02	0.95, 1.10	0.569
Curvilinear component	–	–	–	–	–	–	**F(2.28)=6.56**	–	**<0.001**
Safety from traffic	1.05	0.99, 1.11	0.128	0.99	0.96, 1.01	0.313	0.97	0.93, 1.01	0.101
Safety from crime	**1.07**	**1.00, 1.14**	**0.036**	1.00	0.97, 1.02	0.737	0.98	0.94, 1.02	0.334
Few cul-de-sacs	**0.94**	**0.90, 0.98**	**0.024**	0.99	0.98, 1.01	0.274	0.98	0.95, 1.00	0.059
No major barriers	1.00	0.95, 1.05	0.886	1.00	0.98, 1.02	0.898	1.00	0.97, 1.04	0.795
Proximity to parks	**1.07**	**1.03, 1.11**	**0.031**	1.01	0.99, 1.02	0.213	1.01	0.99, 1.04	0.344

Note. Regression coefficients are adjusted for other perceived environmental characteristics, respondents' age, gender, marital status, educational attainment, work status, and administrative-unit (neighbourhood) socio-economic status. OR = odds ratio; 95%CI = 95% confidence intervals; exp(b) = antilogarithm of regression coefficient; exp(95%CI) = antilogarithm of confidence intervals; – = not applicable.

[a]generalized additive mixed models (GAMMs) with binomial variance and logit link functions.

[b]GAMMs with negative binomial and logarithmic link functions. For these models, exp(b) is to be interpreted as the proportional increase in frequency or duration of walking associated with a 1 unit increase on the perceived environmental attribute scale

Table 4

Site-specific linear associations of perceived aesthetics with duration of walking for recreation among walkers

Country (study site)	exp(b)	exp(95%CI)	p
AUS (Adelaide)	0.97	0.93, 1.01	0.136
BEL (Ghent)	0.97	0.80, 1.18	0.791
BRA (Curitiba)	1.18	0.95, 1.47	0.133
COL (Bogota)	1.07	0.83, 1.38	0.598
CZ (Site A, Olomouc)	1.08	0.83, 1.40	0.547
CZ (Site B, Hradec Kralove)	1.00	0.68, 1.47	0.997
DEN (Aarhus)	1.17	0.96, 1.41	0.115
HK (Hong Kong)	**1.26**	**1.01, 1.56**	**0.037**
MEX (Cuernavaca)	1.06	0.81, 1.40	0.659
NZ (Site C, North Shore)	**1.36**	**1.06, 1.73**	**0.014**
NZ (Site D, Waitakere)	**1.35**	**1.00, 1.82**	**0.048**
NZ (Site E, Wellington)	1.22	0.97, 1.54	0.089
NZ (Site F, Christchurch)	1.09	0.85, 1.39	0.511
ESP (Pamplona)	1.10	0.95, 1.29	0.211
UK (Stoke-on-Trent)	1.01	0.85, 1.19	0.948
USA (Site G, Seattle)	1.01	0.89, 1.17	0.859
USA (Site H, Baltimore)	**1.19**	**1.01, 1.41**	**0.039**

Note. Regression coefficients are adjusted for other perceived environmental characteristics, respondents' age, gender, marital status, educational attainment, work status, and administrative-unit (neighbourhood) socio-economic status, exp(b) = antilogarithm of regression coefficient; exp(95%CI) = antilogarithm of confidence intervals; Estimates were obtained using GAMM with negative binomial and logarithmic link functions. Values of exp(b) are to be interpreted as the proportional increase in non-zero duration of walking (minutes/week) associated with a 1 unit increase on the perceived aesthetics scale (range: 1–4).