Published in final edited form as:
Health Place. 2015 November ; 36: 65–73. doi:10.1016/j.healthplace.2015.09.007.

Moderating effects of age, gender and education on the associations of perceived neighborhood environment attributes with accelerometer-based physical activity: the IPEN Adult study

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ETHICAL APPROVAL
Dr James Sallis is the principal investigator on the IPEN coordinating grant funded by the National Institutes of Health, National Cancer Institute. Ethics Committee approval for the lead grant was obtained from Dr Sallis' institution, the University of California, San Diego, Institutional Review Board (Biomedical Committee) and San Diego State University. Additionally, as a requirement for participation in the IPEN study, all 12 countries providing data obtained approval from the Ethics Committee at each principal investigator's home institution.

CONFLICT OF INTEREST STATEMENT
All authors declare that they have no competing interests.

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Abstract

The study's purpose was to examine age, gender, and education as potential moderators of the associations of perceived neighborhood environment variables with accelerometer-based moderate-to-vigorous physical activity (MVPA). Data were from 7273 adults from 16 sites (11 countries) that were part of a coordinated multi-country cross-sectional study. Age moderated the associations of perceived crime safety, and perceiving no major physical barriers to walking, with MVPA: positive associations were only found in older adults. Perceived land use mix-access was linearly (positive) associated with MVPA in men, and curvilinearly in women. Perceived crime safety was related to MVPA only in women. No moderating relationships were found for education. Overall the associations of adults' perceptions of environmental attributes with MVPA were largely independent of the socio-demographic factors examined. These findings are encouraging, suggesting that efforts to optimize the perceived built and social environment may act in a socially-equitable manner to facilitate MVPA.

INTRODUCTION

Many single-country studies have examined the association between the perceived and objective built and social environment and adults' physical activity (PA) (Arango et al, 2013; Ding & Gebel, 2012; Van Holle et al, 2012). These findings are encouraging, showing consistent associations of some environmental attributes (e.g. walkability, access to services, environmental quality) with PA including active transportation, leisure-time walking and accelerometer-based moderate-to-vigorous PA (MVPA; Ding & Gebel, 2012). Nonetheless, for most other environmental attributes (e.g. aesthetics, safety, proximity to recreation facilities) associations with PA are inconsistent across studies (Bauman et al, 2012). There are many possible explanations for such inconsistencies, such as measurement differences, country-specificity of findings, analytic differences, and failure to account for population-specific effects (Bauman et al, 2012; Sallis et al, 2011). Consequently, there is a strong value in conducting multi-country studies adopting a common protocol, to avoid several of these threats to validity.

Overall, the strength of the contributions of neighborhood built and social environmental attributes to explain PA was modest in previous studies (Bauman et al, 2012). This could be due to the presence of moderating effects: some of the associations between the built environment and PA may differ systematically across socio-demographic groups. Socio-ecological models of health behavior support this rationale, as they posit that behaviors are influenced by an interaction between intrapersonal, socio-cultural, policy and environmental factors (Sallis et al, 2008). Consequently, they suggest that it is important to focus not only on the built and social environment when examining correlates of PA, but also on the interplay with individual-level (e.g. sociodemographics) and socio-cultural (e.g. including various countries/cultures) factors. Previous studies have examined potential moderating effects of socio-demographic factors to establish whether neighborhood environment improvements, or improving residents' environmental perceptions, could lead to sustainable and evenly distributed effects on PA across population subgroups (Gordon-Larsen & Popkin, 2011). Findings have been inconsistent; Forsyth and colleagues (2009) determined the relationship between objective residential density and transport-related walking was strongest in men, lower-educated, unemployed adults and those without children. Similarly, a Canadian study suggested that everyone may benefit from living in an objectively-assessed high walkable neighborhood, but associations with total PA seemed stronger among lower-educated adults (McCormack et al, 2014). In contrast, an Australian study showed objective walkability to be related to walking for transport only in highly-educated adults (Owen et al, 2007). Foster & Giles-Corti (2008) reported positive relationships between perceived crime safety and PA that were stronger among lower-educated, women and older adults. Another study in young adults showed that the association between perceived safety from crime and MVPA was not age- or gender-dependent (Boone-Heinonen & Gordon-Larsen, 2011). Finally, Villanueva and colleagues (2014) concluded that objective neighborhood walkability was supportive of walking, regardless of age.

The available evidence on environment - PA associations identifies possible moderating effects of socio-demographic attributes, but the existence and direction of these relationships may be dependent on the environmental attributes and types of PA studied, and whether objective or perceived environmental factors were included. In some studies, the absence of moderating effects might have been due to insufficient power. Furthermore, although socio-ecological models emphasize the importance of including the interaction with socio-cultural factors in research, no studies previously examined if these moderating effects may be dependent on the country/city one lives in.

In conclusion, there are limitations to what may be inferred from the findings of previous studies examining socio-demographic moderators of environment-PA associations and there is a strong value in conducting multi-country studies. The purpose of the present study was to examine potential moderating effects of gender, education and age on the associations of perceived neighborhood environment attributes with accelerometer-based MVPA (including meeting PA guidelines for weight gain/cancer prevention) in a multi-country study. We also examined whether such moderating effects might vary by study site and estimated the associations of socio-demographic factors with PA outcomes.

METHODS AND MATERIALS

Study design

For this paper, data of the International Physical Environment Network (IPEN) Adult Study were used. IPEN Adult is an observational epidemiologic multi-country cross-sectional study examining associations between the built environment and PA across 17 city-regions (sites) from 12 countries: Australia (Adelaide), Belgium (Ghent), Brazil (Curitiba), Colombia (Bogota), Czech Republic (Olomouc, Hradec Kralove), Denmark (Aarhus), China (Hong Kong), Mexico (Cuernavaca), New Zealand (North Shore, Waitakere, Wellington, Christchurch), Spain (Pamplona), United Kingdom (Stoke-on-Trent), and the USA (Seattle, Baltimore). Data collection dates ranged from 2002 to 2011. For the present analyses, 11 countries (16 sites) with objective accelerometer-based PA data were included (Adelaide, Australia was excluded).

All participants were from neighborhoods stratified into four quadrants: high walkable/high socioeconomic status (SES), high walkable/low SES, low walkable/high SES, and low walkable/low SES. All countries but Spain used an objectively defined walkability index using Geographic Information Systems (GIS) data and census-level SES indicators to select neighborhoods (Kerr et al, 2013). The GIS-based walkability index was computed for all areas across each study site's entire region, using the smallest administrative unit available, then neighborhoods were selected (for details, see Frank et al, 2010; Kerr et al, 2013). Spain used 'construction date' as a parameter for neighborhood selection, which has been associated with walkability (Berrigan & Troiano, 2002).

Ethical approval was obtained from each local institutional review board, and participants' informed consent obtained prior to data collection.

Recruitment and participants

The IPEN-required recruitment strategy systematically selected residents in the selected neighborhoods to participate by completing surveys on their PA and perceptions of their neighborhood environment, and by wearing an accelerometer to objectively assess PA (some countries collected accelerometry only on a subsample). Details about participant recruitment/response rates have been published elsewhere (Kerr et al, 2013). Recruitment age ranged from 15 to 84 years, but only adult participants aged 18-66 years were included. Data from 16 sites in 11 countries (11,572 participants) were analyzed. Not all participants wore an accelerometer, due to no consent (Belgium, Czech Republic, New Zealand and USA) or budget-related inability to collect data from all participants (Brazil, Colombia, Denmark, China, Spain and UK). For the sites aiming to collect accelerometer data from all participants, 86.5% to 100% of participants consented. Compared to those who did not wear accelerometers (n=3304) or had less than four valid days of accelerometer data (n=502), those who had ≥4 valid days of wearing time (n=7,273) were more likely to be older ($p<.001$), married ($p=.012$), employed ($p=.005$), tertiary educated ($p=.001$), and live in perceived crime-safe neighborhoods ($p=.025$) with high pedestrian infrastructure/safety ($p=.043$). No significant differences were found for gender, neighborhood SES, objectively-assessed neighborhood walkability, and the remaining nine perceived neighborhood characteristics. The socio-demographics of the sample with valid accelerometer data are presented in Table 1.

Measures

Neighborhood Environment Walkability Scale (NEWS)—The Neighborhood Environment Walkability Scale (NEWS; Saelens et al, 2003) or NEWS-Abbreviated (Cerin et al, 2006) collected information on built environment perceptions. Confirmatory factor analysis maximized cross-country comparability of sub-scale responses across the 12 IPEN countries (Cerin et al, 2013). The resulting 10 NEWS measures constructed for the IPEN Adult study gauged (1) Residential density; (2) Land use mix – diversity; (3) Land use mix –

access; (4) Street connectivity; (5) Infrastructure/safety for walking; (6) Aesthetics; (7) Traffic safety; (8) Safety from crime; (9) Streets having few cul-de-sacs; and (10) No physical barriers to walking.

The *Residential density* subscale is a weighted sum of items reflecting perceived density of housing, ranging from predominantly single-family dwellings to high-rise buildings of ≥20 stories. The *Land use mix – diversity* scale reflects average perceived walking proximity (i.e., average of five-point ratings ranging from ≤5 to >30 minutes walking: (1) ≤5 minutes, (2) 6-10 minutes, (3) 11-20 minutes, (4) 21-30 minutes, (5) >30 minutes) from home to 9 destinations (supermarket, small grocery/similar stores, post office, schools, transit stop, restaurants, park, gym/fitness facility, and other stores/services). The remaining eight scales were average ratings of items answered on a four-point Likert scale (1= strongly disagree to 4 = strongly agree). Scales were scored in a direction consistent with higher scores for more favorable responses, with individual items reversed when necessary. For detailed items and scoring for each country's scales see Cerin et al (2013).

Accelerometer-measured PA—Mean minutes/day of MVPA were assessed objectively using valid and reliable accelerometers. (Freedson & Miller, 2000; Welk, 2002). Twelve sites used an ActiGraph device (Pensacola, FL), whilst New Zealand sites used the Actical (Philips Respironics, Bend, OR). Data were collected with or aggregated to 1-minute epochs. Non-wear time was defined as ≥60 minutes of consecutive zero counts. Participants were included in analyses if they had ≥4 valid wearing days each with ≥10 valid wearing hours. For Actigraph data, Freedson cut points were used (Freedson et al, 1998). For the Actical data new moderate (730-3399 cpm) and vigorous (≥3400 cpm) intensity cut points were developed to enable comparison with the ActiGraph-Freedson estimates (see Cain 2013). For details on accelerometer data collection and reduction see Cerin et al, (in press).

Daily minutes in each PA intensity were summed across valid wearing days and divided by the number of valid days to compute the average daily minutes of MVPA. An additional binary PA outcome was created corresponding to meeting the PA guidelines for cancer/ weight gain prevention of ≥420 min/week of moderate or ≥210 min/week of vigorous PA (World Cancer Research Fund and American Institute of Cancer Research Guidelines, 2007, Lee et al, 2010, Institute of Medicine, 2002).

Socio-demographic characteristics—Age, gender, education, employment status and marital status were self-reported. As classification of education varied by country, all data were categorized into 'less than secondary school degree', 'secondary school degree' and 'college degree (i.e. 3 or 4 year Bachelor's Degree) or higher (i.e. Master's Degree or PhD)'. Marital status was dichotomized as married/living with a partner versus not. Employment status was recoded as having a paid job: yes or no.

Data Analytic Plan—Descriptive statistics were computed for the whole sample with valid accelerometer data and by study site. Independent associations of perceived environmental variables with PA outcomes and moderating effects of age, education and gender were estimated using generalized additive mixed models (GAMMs; Wood, 2006) accounting for clustering effects at the administrative unit level (Cerin et al., 2014).

GAMMs are very flexible regression models that can be used for outcomes with various distributional assumptions (e.g., normally-distributed, binary or positively skewed outcomes) when data are correlated (i.e., collected in participants living in specific neighborhoods). They can also model curvilinear relationships of unknown form via smoothing terms. In this study, GAMMS with Gamma variance and logarithmic link functions were used for the continuous PA measure (daily minutes of MVPA). GAMMs with binomial variance and logit link functions were used for the dichotomous PA measure (meeting the PA guidelines). The reported antilogarithms of the regression coefficients of these two sets of models represent the proportional increase in daily minutes of MVPA associated with a 1 unit increase in the predictor (risk ratio), and the odds of meeting vs. not meeting the guidelines (odds ratios), respectively.

Main-effect GAMMs estimated the dose-response relationships of all perceived environmental attributes with the continuous and categorical PA outcomes, adjusting for study site, sociodemographics, and unit-level SES. Fully-adjusted (all environmental variables entered) GAMMs were estimated. For all main effects, a two-tailed probability level of 0.05 was adopted. Curvilinear relationships of environmental attributes with outcomes were estimated using non-parametric thin-plate splines in GAMMs (Wood, 2006). Smooth terms failing to provide sufficient evidence of a curvilinear relationship (based on quasi-Akaike Information Criterion; qAIC) were replaced by simpler linear terms (Woods, 2006). Separate GAMMs were run to estimate environmental attributes by socio-demographics (age, education and gender) interaction effects by adding a single two-way interaction term to the main effects models. Another set of models estimated whether moderating effects of socio-demographics by perceived environmental attribute on physical activity outcomes varied by study site. This was done by adding three-way site by socio-demographics by environmental attribute interaction terms to the simpler models with two-way interactions. The significance of the interaction effect was evaluated by comparing qAIC values of models with and without a specific interaction term. An interaction effect was deemed significant if it yielded a qAIC 10 or more units smaller than the main effect model, indicating no support for the simpler main-effect model (Burnham and Anderson, 2002). All significant interaction effects from the single-interaction models were included in final interaction-effect GAMMs (one for daily MVPA and other for the odds of meeting the PA guidelines for weight gain/cancer prevention). These analyses tested for the presence of moderating effects on the multiplicative scale (relative risk and odds ratio scales).

Significant interaction effects were probed by computing gender-, education-, or age-specific associations by study site (as appropriate) using linear combinations of regression coefficients based on the pooled data. Age-specific associations were estimated at average, 1 standard deviation (SD) below, and 1 SD above values of age. Continuous predictors were centered around their mean. As only 305 cases (4.19%) had missing data, data analyses were performed on complete cases (Cerin et al., 2014). All analyses were conducted in R (R Development Core Team, 2013) using the packages ‘car’ (Fox and Weisberg, 2011), ‘mgcv’ (Wood, 2006), and ‘gmodels’ (Warnes, 2012).

RESULTS

Table 1 shows the overall and site-specific descriptive statistics for socio-demographics, accelerometer-based PA outcomes and perceived environmental attributes. The sample consisted of 7273 participants; 54% were women, 50% had a college/university degree, 79% worked, 64% lived with a partner and 20% met the PA guidelines for cancer/weight gain prevention. Mean age was 43 years (SD=12), with mean 38 min/day of MVPA (SD=26.8).

Associations of age, education and gender with PA outcomes

Age was negatively associated with accelerometer-based MVPA and the odds of meeting the PA guidelines for weight gain/cancer prevention (Table 2). For example, a one-year increment in age was associated with a decrease of 0.8% (95% CI: 0.6%, 0.9%) in daily minutes of MVPA and 1.7% (95% CI: 1.2%, 2.2%) lower odds of meeting the PA guidelines. Educational attainment was negatively associated with daily minutes of MVPA only. Women accumulated fewer min/day of MVPA than men and were less likely to meet the PA guidelines (Table 2). The associations of sociodemographics with the PA outcomes did not differ significantly across study sites.

Moderating effects of age, education, and gender on the associations of perceived environmental attributes with PA outcomes

Age moderated the associations of perceived crime safety and having no major barriers to walking (Tables 3 and 4). Specifically, no significant associations with MVPA were found among respondents with a below average and average age, while those with 1 SD above the sample mean showed positive associations (Table 4). No significant evidence was found for moderating effects of age with respect to meeting the weight gain/cancer prevention PA guidelines, nor for moderating effects of education on either of the PA outcomes (Table 3).

Gender moderated the associations of perceived land use mix–access and crime safety with the daily minutes of MVPA and of land use mix–access and street connectivity with the odds of meeting the PA guidelines (Tables 3 and 4). In men, perceived land use mix–access was linearly and positively associated with MVPA, while, in women, this association was curvilinear and positive only at mid-to-high levels of land use mix–access (Figure 1). Perceived safety from crime was positively associated with MVPA only in women (Table 4). Perceived land use mix-access and street connectivity were positively associated with the odds of meeting the weight gain/cancer prevention PA guidelines in men only (Table 4). Moderating effects of socio-demographics and perceived environmental variables on PA outcomes did not vary significantly across study sites and hence, site-specific effects are not reported.

DISCUSSION

These are the first multi-country study findings examining moderating effects of socio-demographic characteristics (age, gender, education) on the relationship between the perceived neighborhood environment and adults' PA. Recently, findings from the IPEN Adult study have indicated that at the individual (within-site) level, the strength of the main associations of perceived environmental attributes with accelerometer-based MVPA was modest (explained 1.2% of the variance in MVPA), with significant effects observed for land use mix-access, aesthetics and safety from crime (Cerin et al, 2014). The present analyses showed that a limited number of moderating effects were present. Thus, most associations of neighborhood built and social environmental attributes with accelerometer-derived MVPA and meeting the weight gain/cancer prevention PA guidelines are generalizable not only across numerous countries (Cerin et al, 2014), but also across socio-demographic subgroups. This illustrates that relatively few of the significant findings varied by demographic subgroup. This novel finding in the context of identifying potential environmental and policy interventions suggests that optimizing perceptions of neighborhood aesthetics and land use mix–access (Cerin et al, 2014) may be effective for adult populations in general. However, this also means that the previously identified 'modest' contributions of perceived environmental attributes explaining MVPA (Cerin et al, 2014) remain modest across the socio-demographic groups examined. Two of the associations between environmental perceptions and MVPA were age-dependent. The positive relationship of perceived safety from crime and perceiving no major barriers to walking with MVPA was only significant in 'older' adults (1SD above the sample mean, i.e. approximately 55 years). Furthermore, perceptions of crime safety were only positively related to MVPA in women. Previously, it has been argued that women and older adults, who are more physically vulnerable, have more concerns about personal safety (Foster & Giles-Corti, 2008; Roman & Chalfin, 2008); hence this may explain why positive associations were only found in this subgroup. Some studies found safety concerns restricted PA in both men and women, as well as younger and older adults, while others did not find any associations (Foster & Giles-Corti, 2008). These mixed results may be due to the fact that crime safety is often not clearly defined in questionnaires. In IPEN, the 11 countries showed large variability in perceived crime safety (e.g. low in Brazil and Colombia; high in Denmark and New Zealand), possibly providing a more complete picture of the true associations and moderating effects in comparison with single-country studies.

Gender also moderated associations between perceived land use mix-access and both outcome measures, and between perceived connectivity and the odds of reaching the weight gain/cancer prevention PA guidelines. Street connectivity was only positively related to the odds of reaching the PA guidelines in men. Land use mix-access was linearly and positively related to both outcomes in men, and curvilinearly (only positive at mid-to-high levels of land use mix-access) to min/day of MVPA in women. There is no simple explanation for these findings. Boone-Heinonen et al (2011) suggested that perceptions of high connectivity may induce more heavy traffic, and that women rather than men may perceive this as a barrier for PA, possibly explaining the non-significant association with MVPA in women. Furthermore, the two built environment variables may be mainly related to meeting weight gain/cancer prevention PA guidelines in men because too few women meet these high guidelines, reducing power. No previous studies described a curvilinear association between land-use-mix access and MVPA in women, possibly because the statistical techniques used in other studies did not allow the detection of curvilinear associations, whilst in this analysis the GAMMs/regression methods were able to describe (curvi)linear associations. Future studies should consider this method, as our findings show that the associations between the perceived built environment and PA can be curvilinear. However, the curvilinear association identified here should be interpreted with caution: very few women reported low perceived access to services (mean scale score <2.0 out of 4.0), resulting in large confidence intervals at the lower end of the curve. Educational attainment did not moderate any of the associations between the perceived environment and MVPA or reaching the PA guidelines for weight gain/cancer prevention. Previous single-country studies have reported mixed results on the moderating effects of education: some reporting stronger associations in less-educated adults (Forsyth et al, 2009; McCormack et al, 2014; Pearce & Maddison, 2011), while others finding stronger relationships of neighborhood walkability and pedestrian safety with walking for transport (Owen et al, 2007) or total MVPA (Carlson et al, 2014) in more highly-educated adults. However, all but one (Carlson et al, 2014) of these previous studies used objective measures to assess the built environment. As it has been shown that the agreement between the objective and perceived environment is limited and both can be related differently to PA (McCormack et al, 2008; McGinn et al, 2007), it might be the case that mainly the relationship between objective environmental factors and PA is moderated by educational level. To draw definite conclusions on the role of education in moderating the relationship between the physical environment and PA, more large-scale multi-country studies, preferably with a prospective design, are needed.

The heterogeneity in moderating effects found here, and in previous studies might be due to methodological and cultural factors, differences in outcome measures, measurement methods and survey item interpretations, or response biases. Nonetheless, the absence of moderating effects of education indicates that lower-educated adults, who are difficult to reach through individual interventions and are more susceptible to being insufficiently active (Sallis et al, 2009; Trost et al, 2002), might benefit from initiatives targeting improvements in perceptions of neighborhood environment characteristics such as aesthetics, land use mix-access and safety from crime (Cerin et al, 2014) as much as their higher-educated counterparts.

As a secondary aim, we examined the country-specificity of the associations of gender, age and education with the PA outcomes and of the moderating effects of these socio-demographic factors. Regarding the main associations between the socio-demographics and the PA outcomes, the findings were generally in line with previous studies (Trost et al, 2002), with older adults and women being less active than younger adults and men. More highly-educated adults accumulated fewer min/day of MVPA than lower-educated adults, possibly due to work-related MVPA being higher in less-educated adults, as they are more likely to do manual work. Concerning the moderating effects of gender, age and education on the relationship between the perceived environment and PA, no country-specific findings were revealed: all results were generalizable across the 11 participating countries. The examination of the country-specificity of these associations and moderations is a very innovative part of the current analyses, taking into account the ‘socio-cultural layer’ of socioecological models (Sallis et al, 2008): because no country-specific findings were discovered this suggests that cultural differences between countries did not affect the relationship between socio-demographic factors and accelerometer-based MVPA nor the moderating effects of sociodemographics on the association between the perceived environment and MVPA. Although previous analyses using the same data (Cerin et al, 2014) showed some differences in the main associations between the perceived environment and accelerometer-based MVPA by study site (e.g. aesthetics were positively related to MVPA in the USA, but negatively in Belgium), the moderation of such relationships by sociodemographic factors is not different across countries.

Although the present study had several strengths, including the large sample size, comparable data collection protocols across 11 countries' cities/regions, objective measures of MVPA, use of a valid questionnaire to assess environmental perceptions, and application of advanced statistical models that allowed for curvilinear associations, some limitations are acknowledged. First, the results may not be generalizable to the total population in the participating countries, as participants were recruited from specific neighborhoods based on their walkability and income levels. Second, response rates, survey methods and accelerometer models used varied across study sites. This may imply sampling biases or other methodological biases across study sites. Third, accelerometers do not take into account context-specific information of PA, which would have helped to better understand the moderating effects that were identified, nor do they accurately measure all activities (e.g. cycling, swimming, resistance training). Fourth, only perceived environmental attributes were included in this paper; within IPEN Adult objective GIS-based measures are also available, but they measure fewer environmental variables.

In summary, present findings from an 11-country study add important knowledge about the possible moderating effects of socio-demographic factors on the relationship between the perceived built environment and accelerometer-based PA. Some moderating effects of age and gender were present, but overall the associations between environmental perceptions and accelerometer-based MVPA, expressed as odds ratios and risk ratios, were independent of age, sex, and education. Future studies should focus on other potential moderators such as psychosocial factors (Van Dyck et al, 2009). The novel findings presented here are encouraging, and suggest that international efforts to optimize the perceptions residents have of their built and social environments (mainly land use mix-access and aesthetics) may facilitate engagement in MVPA in men and women, younger and older adults, and higher- and lower-educated adults worldwide. Nonetheless, confirmatory prospective studies are needed to elicit stronger recommendations.

Acknowledgments

FUNDING

All authors declare financial support for the submitted work from the National Cancer Institute of the National Institutes of Health. US data collection and Coordinating Center processing was supported by the following NIH grants: R01 HL67350 (NHLBI) and R01 CA127296 (NCI). Data collection in Hong Kong was supported by the grants (#HKU740907H and #747807H) and the HKU URC Strategic Research Theme (Public Health). The study conducted in Bogota was funded by Colciencias grant 519 2010, Fogarty and CeiBA (Center in Complex-Systems, Basic and Applied Research at the Universidad de los Andes). The contributions of Neville Owen were supported by a NHMRC Program Grant (#569940), a NHMRC Senior Principal Research Fellowship (#1003960), and by the Victorian Government's Operational Infrastructure Support Program. The Danish study was partly funded by the Municipality of Aarhus. Data collection in the Czech Republic was supported by the grant MEYS (# MSM 6198959221). Data collection in New Zealand was supported by the Health Research Council of New Zealand grant # 07/356. Data collection in Mexico was supported by the CDC Foundation which received an unrestricted training grant from The Coca-Cola Company. Data collected for the UK was in part funded by the Medical Research Council (NPRI Initiative), grant number: 75376. Olga L Sarmiento received a research grant from the Coca Cola Company outside of submitted work. Delfien Van Dyck is funded by the Research Foundation Flanders, outside of submitted work. James F Sallis received grants and personal fees from the Robert Wood Johnson Foundation outside of submitted work, grants and non-financial support from Nick, Inc. outside of submitted work, is a Santech, Inc. shareholder and is a consultant and receiver of royalties from SPARK Programs of School Specialty, Inc. The results of the present study do not constitute endorsement by the ACSM. The funding bodies had no input in study design and the collection, analysis and interpretation of data and the writing of the article and the decision to submit it for publication. All authors are independent from the funding bodies.

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Highlights

- Previous studies showed inconsistent associations of the environment with MVPA
- Moderating effects may explain these inconsistent associations
- The moderating effects of age, gender and education were rather limited
- Optimizing land use mix and aesthetics may facilitate MVPA in whole adult populations

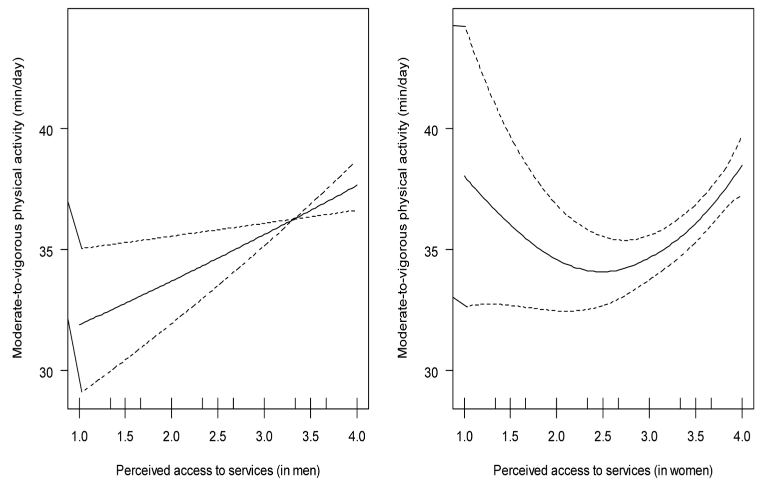

Figure 1. Relationships between perceived land use mix – access and average daily minutes of accelerometer-based moderate-to-vigorous PA in men and women

Note. The solid line represents point estimates (and dashed line their 95% confidence intervals) of average daily minutes of moderate-to-vigorous physical activity at various levels of perceived land use mix – access. These estimates were computed at average values of other environmental variables and covariates.

Table 1

Sample characteristics: socio-demographic information, accelerometer-based PA outcomes and perceived environmental attributes

	ALL SITES	BEL[1]	BRA[2]	COL[2]	CZE[1]		DEN[2]	HK[2]	MEX[1]	NZ[1]				SP[2]	UK[2]	USA[1]	
					Site A	Site B				Site C	Site D	Site E	Site F			Site G	Site H
N with ≥4 day valid PA data (% *sample*)	7,273 (51)	1,050 (99)	330 (47)	223 (23)	258 (78)	122 (73)	272 (42)	269 (56)	656 (97)	373 (73)	399 (78)	416 (84)	373 (75)	329 (36)	135 (16)	1198 (93)	870 (95)
Age, years *Mean (SD)*	43 (12)	43 (13)	42 (13)	46 (12)	39 (14)	36 (14)	40 (14)	42 (13)	42 (13)	43 (12)	42 (11)	40 (12)	43 (12)	39 (13)	44 (13)	44 (11)	47 (11)
Gender, *%men*	45.9	48.5	48.5	31.8	36.0	38.6	39.0	40.5	45.7	37.4	40.4	47.6	45.6	39.5	46.7	55.0	48.7
Education, %																	
Less than HS	12.1	4.3	27.9	46.6	23.0	15.7	7.4	36.4	43.9	2.4	3.8	0.5	8.6	4.3	38.8	1.1	1.8
HS graduate	38.4	32.7	31.2	36.3	43.5	56.5	42.3	23.1	28.8	58.3	64.7	45.0	57.0	32.7	46.3	34.9	29.6
College or more	49.5	62.9	40.9	17.0	33.5	27.8	50.4	40.5	27.3	39.3	31.6	54.6	34.4	63.0	14.9	64.0	68.5
Work status, *%working*	78.8	80.3	79.4	60.5	77.9	82.8	75.4	62.7	71.5	76.4	86.2	87.5	85.5	76.3	64.4	81.4	83.0
Marital status, *%couple*	64.3	73.4	60.3	61.4	60.3	52.6	69.1	56.1	64.8	71.1	76.1	60.1	57.1	57.3	45.9	64.1	61.1
Valid days of accelerometer wear time, *Mean (SD)*	6.5 (1.1)	6.7 (1.1)	6.7 (1.0)	6.6 (1.0)	6.2 (1.2)	6.2 (1.4)	7.0 (0.8)	5.9 (1.0)	5.7 (1.0)	6.4 (1.3)	6.4 (1.3)	6.7 (1.3)	6.5 (1.3)	6.5 (0.8)	6.6 (1.0)	6.7 (0.8)	6.7 (1.2)
Accelerometer wear time (hrs/day) *Mean (SD)*	14.4 (1.3)	14.7 (1.3)	14.0 (1.3)	13.9 (1.2)	13.9 (1.4)	14.2 (1.3)	14.9 (1.1)	14.4 (1.4)	14.0 (1.4)	14.2 (1.2)	14.1 (1.3)	14.0 (1.2)	14.0 (1.2)	15.0 (1.1)	14.6 (1.2)	14.7 (1.3)	14.8 (1.4)

	ALL SITES	BEL[1]	BRA[2]	COL[2]	CZE[1]		DEN[2]	HK[2]	MEX[1]	NZ[1]				SP[2]	UK[2]	USA[1]	
					Site A	Site B				Site C	Site D	Site E	Site F			Site G	Site H
MVPA (min/day) *Mean (SD)*	38.0 (26.8)	35.5 (23.5)	31.5 (24.6)	37.0 (26.4)	47.1 (27.7)	45.1 (25.9)	39.7 (23.2)	44.9 (25.3)	31.2 (25.2)	45.7 (28.4)	37.2 (29.2)	50.1 (31.0)	44.0 (32.5)	51.0 (29.5)	36.7 (27.3)	36.3 (24.9)	29.2 (22.0)
PAG for cancer and weight gain prevention, *%*	19.7	15.5	13.9	16.1	29.8	29.5	24.3	27.5	12.3	27.9	16.3	30.0	25.2	31.3	19.3	18.9	12.9
Residential density (0-1000), *Mean (SD)*	74.6 (112.7)	82.6 (72.6)	99.7 (123.6)	51.7 (59.6)	89.1 (68.6)	85.1 (68.8)	83.5 (63.4)	443.8 (216.2)	38.1 (40.9)	30.0 (49.9)	19.1 (26.4)	45.5 (65.5)	22.7 (26.7)	187.0 (102.3)	36.2 (32.5)	37.5 (53.9)	59.9 (79.4)
Land use mix – access (1-4), *Mean (SD)*	3.3 (0.7)	3.3 (0.6)	3.6 (0.5)	3.4 (0.4)	3.5 (0.6)	3.4 (0.6)	3.6 (0.6)	3.5 (0.7)	3.3 (0.5)	3.2 (0.6)	3.1 (0.5)	3.4 (0.5)	3.4 (0.5)	3.7 (0.5)	3.4 (0.7)	3.2 (0.8)	3.0 (0.8)
Land use mix – diversity (1-5), *Mean (SD)*	3.8 (0.8)	3.6 (0.9)	4.1 (0.5)	4.2 (0.4)	3.9 (0.6)	4.0 (0.6)	4.2 (0.6)	4.1 (0.7)	3.7 (0.6)	3.8 (0.6)	3.7 (0.7)	4.1 (0.6)	3.9 (0.6)	4.5 (0.4)	3.7 (0.5)	3.8 (0.8)	3.6 (0.9)
Street connectivity (1-4), *Mean (SD)*	3.0 (0.7)	2.7 (0.7)	3.3 (0.7)	3.1 (0.6)	3.0 (0.7)	3.0 (0.6)	3.1 (0.6)	3.2 (0.8)	2.9 (0.5)	2.7 (0.5)	2.7 (0.4)	2.8 (0.5)	3.0 (0.5)	3.3 (0.7)	3.1 (0.7)	3.0 (0.8)	3.0 (0.8)
Infrastructure and safety (1-4), *Mean (SD)*	2.9 (0.6)	2.8 (0.5)	2.8 (0.8)	2.8 (0.5)	3.1 (0.5)	3.2 (0.5)	3.1 (0.5)	3.4 (0.6)	2.6 (0.4)	2.8 (0.3)	2.8 (0.4)	2.9 (0.4)	3.0 (0.4)	3.4 (0.5)	3.2 (0.5)	3.0 (0.6)	3.1 (0.6)

	ALL SITES	BEL[1]	BRA[2]	COL[2]	CZE[1]		DEN[2]	HK[2]	MEX[1]	NZ[1]				SP[2]	UK[2]	USA[1]	
					Site A	Site B				Site C	Site D	Site E	Site F			Site G	Site H
Aesthetics (1-4), *Mean (SD)*	2.8 (0.7)	2.6 (0.6)	2.9 (0.8)	2.4 (0.5)	2.4 (0.6)	2.6 (0.5)	2.7 (0.6)	2.8 (0.7)	2.6 (0.5)	2.8 (0.5)	2.9 (0.5)	2.8 (0.5)	2.8 (0.6)	2.7 (0.7)	2.3 (0.8)	3.1 (0.7)	3.1 (0.6)
Traffic safety (1-4), *Mean (SD)*	2.6 (0.6)	2.4 (0.6)	2.4 (0.8)	2.4 (0.5)	2.9 (0.6)	3.1 (0.5)	2.9 (0.5)	2.9 (0.6)	2.4 (0.5)	2.6 (0.5)	2.6 (0.5)	2.8 (0.4)	2.7 (0.5)	2.5 (0.7)	2.5 (0.7)	2.7 (0.7)	2.7 (0.7)
Crime safety (1-4), *Mean (SD)*	3.1 (0.7)	3.2 (0.5)	2.3 (0.5)	1.9 (0.6)	3.2 (0.6)	3.4 (0.5)	3.3 (0.6)	3.4 (0.6)	2.2 (0.7)	3.1 (0.5)	2.9 (0.4)	3.1 (0.4)	2.9 (0.6)	3.6 (0.6)	3.0 (0.7)	3.4 (0.6)	3.4 (0.7)
Few cul-de-sacs (1-4), *Mean (SD)*	2.8 (1.0)	3.0 (0.8)	2.9 (1.1)	2.7 (0.8)	2.9 (1.0)	3.0 (0.9)	2.8 (0.9)	3.5 (0.8)	2.6 (0.7)	2.3 (0.6)	2.3 (0.6)	2.5 (0.7)	2.5 (0.8)	3.6 (0.9)	2.3 (1.0)	2.8 (1.1)	2.8 (1.2)
No major barriers to walking (1-4), *Mean (SD)*	3.3 (0.8)	3.3 (0.7)	3.1 (1.1)	2.9 (0.7)	3.4 (0.8)	3.5 (0.8)	3.7 (0.6)	3.3 (1.0)	2.8 (0.7)	3.3 (0.6)	3.2 (0.6)	3.3 (0.5)	3.5 (0.7)	3.6 (0.8)	3.4 (0.8)	3.2 (1.0)	3.8 (0.6)

Notes: Site A: Olomouc, B: Hradec Kralove, C: North Shore, D: Waitakere, E: Wellington, F: Christchurch, G: Seattle, H: Baltimore; HS=high school; PA=physical activity; MVPA = moderate-to-vigorous physical activity; PAG = physical activity guidelines for weight gain/cancer prevention; SD = standard deviation; valid days of accelerometer wear are those with 10+ valid hours of wear; for the perceived environmental attributes, the theoretical range of answers is reported between brackets.

[1] Study site aimed to collect accelerometer data in the total sample

[2] Study site aimed to collect accelerometer data in a fixed proportion of the total sample

Table 2

Associations of age, education and gender with PA outcomes

Socio-demographic factor	**Moderate-to-vigorous PA (min/day)**[a]		**Meeting the PA guidelines for weight gain / cancer prevention**[b]	
	exp(b) exp(95% CI)	**p**	**OR (95% CI)**	**P**
Age	0.992 (0.991, 0.994)	<.001	0.983 (0.978, 0.988)	<.001
Education (reference: less than high school graduate)				
High school graduate and/or some college	0.916 (0.863, 0.970)	.003	0.861 (0.685, 1,083)	.203
College degree or higher	0.924 (0.870, 0.981)	.010	0.809 (0.640, 1.023	.078
Gender (reference: men)				
Women	0.795 (0.770, 0.821)	<.001	0.527 (0.466, 0.596)	<.001

Notes. OR = odds ratio; PA=physical activity; 95% CI = 95% confidence interval; exp(b) antilogarithm of regression coefficient; exp(95% CI) = antilogarithm of confidence interval. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status, administrative-unit socio-economic status, and accelerometer wear time.

[a]generalized additive mixed model (GAMM) with Gamma variance and logarithmic link functions, for which exp(b) is interpreted as the proportional increase in PA associated with a 1 unit increase in the predictor.

[b]GAMM with binomial variance and logit link functions.

Table 3

Summary results of moderating effects of age, education and gender on the associations of perceived neighborhood environment attributes and PA outcomes[a]

Environmental attribute	Physical activity outcome	Age	Education	Gender
Residential density	MVPA (min/day)	−4.64	−1.39	−1.40
	Meeting PA guidelines	−17.32	−3.10	5.04
Land use mix – access	MVPA (min/day)	2.88	−10.58	**11.12** *
	Meeting PA guidelines	−36.17	−8.17	**13.79** *
Land use mix – diversity	MVPA (min/day)	4.42	−3.87	−0.88
	Meeting PA guidelines	−15.09	1.60	−4.64
Street connectivity	MVPA (min/day)	0.95	−4.23	3.61
	Meeting PA guidelines	−21.26	−11.52	**10.00** *
Pedestrian infrastructure and safety	MVPA (min/day)	7.45	−3.17	−2.34
	Meeting PA guidelines	−9.00	−11.49	2.17
Aesthetics	MVPA (min/day)	8.94	−2.64	7.48
	Meeting PA guidelines	−9.09	−12.32	−4.52
Traffic safety	MVPA (min/day)	−2.10	9.48	9.48
	Meeting PA guidelines	−4.09	−1.03	−7.54
Safety from crime	MVPA (min/day)	**14.70** *	1.45	**25.66** *
	Meeting PA guidelines	−20.10	−21.41	−13.60
Few cul-de-sacs	MVPA (min/day)	−2.43	−1.60	4.38
	Meeting PA guidelines	−4.09	−2.54	−0.08
No major barriers to walking	MVPA (min/day)	**17.28** *	−3.94	3.30
	Meeting PA guidelines	−15.15	−10.74	−10.27

Notes. MVPA=moderate-to-vigorous physical activity; PA=physical activity;

[a]Values represent differences between quasi-Akaike Information Criterion values of main- and interaction-effect models.

*Values equal to or greater than 10 are indicative of no support for the simpler, main-effect model and support for the interaction effect.

Table 4

Age- and gender-specific associations of perceived environmental attributes with the PA outcomes

	Moderate-to-vigorous PA (min/day)			Meeting the PA guidelines for weight gain / cancer prevention		
Moderator : Environmental attribute	**exp(b)**	**exp(95% CI)**	**p**	**OR**	**95% CI**	**p**
Age : Safety from crime						
Association at −1 SD below mean age	0.985	0.948, 1.022	.422	-	-	-
Association at mean age	1.017	0.987, 1.049	.266	-	-	-
Association at 1 SD above mean age	**1.053**	**1.015, 1.094**	**.007**	-	-	-
Age : No major barriers to waking						
Association at −1 SD below mean age	0.987	0.957, 1.018	.420	-	-	-
Association at mean age	1.016	0.994, 1.038	.158	-	-	-
Association at 1 SD above mean age	**1.040**	**1.010, 1.017**	**.009**	-	-	-
Gender : Land use mix - access						
Association in men (Linear)	**1.038**	**1.011, 1.065**	**.006**	**1.186**	**1.015, 1.385**	**.032**
Association in women (Linear)	1.009	0.937, 1.086	.819	1.149	0.965, 1.368	.120
Associations in women (Curvilinear; see Figure 1)	**F (2.39, 2.39) = 7.06**		**<.001**	-	-	-
Gender : Street connectivity						
Association in men	-	-	-	**1.156**	**1.005, 1.328**	**.042**
Association in women	-	-	-	1.026	0.882, 1.192	.741
Gender : Safety from crime						
Association in men	0.982	0.944, 1.020	.350	-	-	-
Association in women	**1.050**	**1.013, 1.088**	**.009**	-	-	-

Notes. PA=physical activity. All regression coefficients are adjusted for respondents' age, gender, marital status, education, employment status, administrative-unit (neighborhood) socio-economic status and perceived environmental attributes. Linear = linear regression term. Curvilinear = curvilinear regression term. exp(b) = antilogarithm of regression coefficient, to be interpreted as the proportional increase in the outcome with a 1 unit increase on the predictor; exp(95% CI) = antilogarithm of confidence intervals; OR = odds ratio; 95% CI: 95% confidence intervals; - = not applicable.