Associations of Neighborhood Environmental Attributes with Adults' Objectively-Assessed Sedentary Time: IPEN Adult Multi-Country Study

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Abstract

Objectives: To identifying potential relationships of neighborhood environmental attributes with objectively-assessed sedentary time, across multiple countries.

Methods: Participants (n = 5,712) were recruited from neighborhoods in 12 sites in 10 countries. Ten perceived neighborhood attributes, derived from an internationally-validated scale, were assessed by questionnaire. Sedentary time was derived from hip-worn accelerometer data. Associations of individual environmental attributes and a composite environmental index with sedentary time were estimated using generalized additive mixed models.

Results: Higher street connectivity was significantly related to lower sedentary time; residential density, pedestrian infrastructure and safety and lack of barriers to walking were related to higher sedentary time. Aesthetics and safety from crime were related to less sedentary time in women only. The predicted difference in sedentary time between those with the minimum and maximum composite index values was 71 min/day.

Conclusions: Built environment attributes associated with physical activity, including street connectivity, land use mix and aesthetics are also related to sedentary behavior. With appropriate environmental enhancements, there is potential for synergistic health benefits through population-level increases in physical activity and reductions in sedentary time.

INTRODUCTION

High volumes of sedentary (sitting) time can be associated – after accounting for moderate-to-vigorous activity – with premature mortality and other health problems (1, 2). Adults can spend a majority of their waking hours sitting (3, 4). For example, the US National Health and Nutrition Examination Survey found that those in the top sedentary quartile spent on average 10.2 hours per day sedentary (5).

In order to pursue broad-based changes in sedentary time, environmental and policy initiatives are required (6, 7). Similar to associations observed between aspects of the built environment and physical activity (6), sedentary behavior may be influenced by surrounding environmental conditions. It is possible, for example, that unsafe or unattractive neighborhood environments may lead to less leisure time physical activity and thus more time spent in TV viewing and other indoor engagements that involve primarily sitting. For example, higher levels of perceived safety and the presence of street lighting have been found to be associated with lower levels of TV viewing among older Belgian adults (8) and lower levels of sitting among Hong Kong older adults (9). found that neighborhood aesthetics and safety concerns such as litter, dogs and being outdoors after dark were associated with higher levels of TV viewing among African-American women, but not men (10). Other perceived neighborhood attributes related to walking assessed using the Neighborhood Environment Walkability Scale (NEWS) (11, 12) have been found to be related to sitting time among Australian and US adults (13), but a recent review identified a modest and inconsistent pattern of associations within the published studies (14).

With the exception of one multi-country study (13), the evidence on environmental correlates of sedentary behaviors arises from single countries. It is possible that non-significant or weak associations reported in single-country studies may be due partly to limited variation in environmental attributes. Studies involving multiple countries can fill this gap by providing broader environmental variance (15). Such studies have also employed self-report measures of sedentary time (14), with the exception of one study conducted in Belgium (16) and one in the USA (17). Given the ubiquitous nature of sedentary behaviors – making the recall of time spent sitting difficult – objectively assessed sedentary time can provide more robust evidence on environmental correlates (18).

We examined the associations of perceived neighborhood environmental attributes with accelerometer-derived overall sedentary time across 10 countries. We also examined site-specific and gender-specific associations.

METHODS

Study design

The IPEN (International Physical Activity and the Environment Network) Adult study is an observational, epidemiologic, multi-country, cross-sectional study, including 17 city-regions (hereafter, 'sites') located within 12 countries worldwide: 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), the United Kingdom (Stoke-on-Trent) and the United States (Seattle, Baltimore). For the present analyses, data were included from 12 sites in 10 countries (excluding Australia and New Zealand) that used ActiGraph accelerometers.

Study participants were recruited from neighborhoods chosen to maximize variance in neighborhood walkability and income. For selection of neighborhoods, all countries but one (Spain) used a neighborhood walkability index that was measured objectively with Geographic Information Systems (GIS) data at the smallest administrative unit available. The neighborhood-selection techniques employed in each country can be found elsewhere (19). For every administrative unit across study sites, the walkability index was derived as a function of at least two of the following variables: net residential density, land use mix and intersection density. In four countries, retail floor area ratio was also included in the index as a proxy for pedestrian-oriented design. The walkability index is described in more detail elsewhere (20, 21). In each country, administrative units were ranked based on the walkability index and household-level income data from the census; the selection procedure resulted in an equal number of neighborhoods among four pre-specified types (quadrants), stratified as follows: high-walkable/high-income, high-walkable/low-income, low-walkable/high-income, and low-walkable/low-income.

Participant recruitment

IPEN used a systematic strategy to recruit participants. Random samples of adults living in the selected neighborhoods were contacted and invited to wear an accelerometer for objective physical activity assessment. Three countries recruited and conducted data collection by phone and mail/online surveys and six countries visited participants in person to deliver study materials. In Hong Kong, intercept interviews were conducted in residential areas where individual addresses were not available (e.g., high-rise apartments). Study dates ranged from 2002 to 2011Further details on the participant recruitment techniques and response rates across countries can be found elsewhere (19).

Of the 9,065 potential participants, 3,100 were not part of the accelerometer subsample per country or had missing accelerometer data and 253 had less than four valid (at least 10 wearing hours) days of data, yielding a final sample of 5,712. Compared to potential participants who were excluded, those with valid accelerometer data were more likely to be older ($p<.001$), married or in a defacto relationship ($p<.001$), employed ($p=.014$), and living in neighborhoods perceived to have higher levels of safety from crime ($p=.037$). The socio-demographic characteristics of the sample with valid accelerometer data, by study site, are presented in Table 1.

Quality control

All country investigators completed San Diego State University Institutional Review Board training, and met the NIH Fogarty International Center and their own country's ethics requirements. All study participants provided informed consent for participation in their country-level study and all countries obtained ethical approval from their relevant ethics committees. Participant confidentiality for pooled data was maintained by de-identification using numeric identification codes. For data transfer, a secure file sharing system was used. Survey data were assessed for completeness by the study sites and double-checked by the central IPEN coordinating center. Accelerometer data were provided in pre-processed format (i.e. DAT or CSV files) to the central IPEN coordinating center. Trained researchers at the coordinating center screened and scored all data using MeterPlus software version 4.3. (www.meterplussoftware.com). Protocols for screening data were developed for different accelerometer models, methods of deployment, available documentation of wearing time, and cultural differences in activity patterns.(22).

Measures

Neighborhood Environment Walkability Scale (NEWS)

The NEWS assesses perceived neighborhood attributes related to walking (11, 12), but has been also found to be related to sedentary behavior (13). Because the IPEN Adult study is an aggregate of studies conducted at different times (some with data collection completed prior to joining the IPEN study), the NEWS items collected across countries were not all identical. To maximize the number of participating countries and participant sample sizes, previous validation work compared the NEWS/NEWS-A items used in each country and confirmed scales could be constructed that were comparable across the 12 IPEN countries (15). The resulting 10 NEWS measures constructed for the IPEN Adult study gauge the following perceived neighborhood attributes: (1) Residential density; (2) Land use mix – diversity; (3) Land use mix – access; (4) Street connectivity; (5) Infrastructure and 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 presence of dominant housing types, ranging from predominantly single-family dwellings to high-rise buildings with more than 20 stories. *Land use mix – diversity* reflects average perceived walking proximity (i.e., average of five-point ratings ranging from ≤5 minute walk to 30+ minute walk) from home to nine types of destinations: supermarket, small grocery or similar stores, post office, any school, transit stop, any restaurant, park, gym or fitness facility, and other stores and services. The remaining eight scales are 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 walkability and safety, with individual items reversed when necessary. Exact items and scoring for each country's scales are provided in detail in Cerin et al. (15).

<u>Objectively-assessed sedentary time (main outcome) and physical activity (covariate)</u>

Total minutes/day of sedentary time and total minutes/day of moderate-to-vigorous intensity physical activity (MVPA) were derived using accelerometer data. Reliability and validity properties of accelerometers have been documented extensively (23, 24). In three countries accelerometers were mailed to participants and in others they were hand-delivered and retrieved. Participants were asked to wear the accelerometer above the right hip for seven consecutive days during waking hours and to remove it only for water activities (e.g. swimming, bathing). ActiGraph accelerometer models used in the study included the 7164 model, 71256 model, GT1M, ActiTrainer and GT3X models (Pensacola FL)(25).

Accelerometer data were collected in (or aggregated to) one-minute epochs. Data were processed using MeterPlus version 4.3. Non-wear time was defined as 60 minutes or more of consecutive zero counts. Counts per minute were converted into estimated minutes of sedentary time (≤100 counts/min), moderate- (1952-5724 counts/min), and vigorous-intensity (5725+ counts/min) physical activity (26).

<u>Socio-demographic characteristics</u>

Age, gender, educational level and marital status of the participants were assessed and included as covariates in all statistical models. While types of education varied by country, all country data could be categorized into 'having university degree', 'having high school diploma' and 'having less than high school diploma'. Marital status was dichotomized into living with a partner / spouse versus not living with a partner /spouse. .

Data analyses

Descriptive statistics were computed for the whole sample and by study site. Associations of perceived environmental attributes with objectively-measured sedentary time were estimated using generalized additive mixed models (GAMMs). GAMMs can model data following various distributional assumptions, account for dependency in error terms due to clustering (participants recruited from selected administrative units), and estimate complex, dose-response relationships of unknown form (27). Preliminary analyses based on residuals and Akaike's Information Criterion (AIC, a measure of model fit) indicated that GAMMs with Gaussian variance and identity link functions would be most appropriate to model objectively-measured sedentary time.

Main-effect GAMMs estimated the dose-response relationships of perceived environmental attributes with objectively-measured sedentary time, adjusting for study site, socio-demographic covariates, objectively-measured MVPA, accelerometer wear time and area-level socio-economic status. We estimated separate covariate-adjusted GAMMs for each environmental attribute (single environmental-attribute models) and for all environmental attributes entered in the model simultaneously (multiple environmental-attribute models).

A composite environmental index was constructed by summing up the standardized scores (z-scores) of the environmental attributes that were positively related, and subtracting the standardized scores of variables that were negatively related, to sedentary time (in any of the GAMMs). GAMMs with the composite environmental index as a predictor of sedentary time were estimated.

Curvilinear relationships were estimated using non-parametric smooth terms in GAMMs, which were modeled using thin-plate splines (27). Smooth terms failing to provide sufficient evidence of a curvilinear relationship (based on AIC) were replaced by simpler linear terms. Separate GAMMs were run to estimate sedentary time by study site and by gender interaction effects (two-way and three-way interactions). The significance of interaction effects was evaluated by comparing AIC values of models with and without a specific interaction term. An interaction effect was deemed significant if it yielded a >2-unit smaller AIC than the main effect model (28). Significant interaction effects were probed by computing the site- and/or gender-specific association.

Fewer than 5% of cases (4.5%; n=256) had missing data. Thus, analyses were performed on complete cases (29). Participants with missing data were more likely to be women (p=.021), have fewer valid hours (p=.003) and days (p=.027) of accelerometer wear time, report lower perceived neighborhood aesthetics (p=.004), and be less likely to hold a tertiary degree (p=.025). All analyses were conducted in R using the packages 'car' (30), 'mgcv' (27) and 'gmodels' (31).

RESULTS

Table 1 shows sample characteristics and overall and site-specific sample characteristics, including average daily objectively-assessed sedentary time. Mean sedentary time of all sites was 8.5 hours/day (59% of accelerometer wearing time), ranging from 7.7 hours/day in Bogota (Colombia, 56% of wear time) to 9.5 hours/day in Aarhus (Denmark, 64% of wear time). Other sites with lower levels of sedentary time were Cuernavaca (Mexico) and Curitiba (Brazil). Pamplona (Spain), Hong Kong (China), and Baltimore (USA) had higher average amounts of sedentary time. Table 2 shows the overall and site-specific mean values and standard deviations for the perceived environmental attributes.

INSERT TABLES 1 & 2 ABOUT HERE

Associations of specific environmental attributes with sedentary time

The single environmental-variable models identified five significant environmental correlates of sedentary time (Table 3). Higher street connectivity was significantly related to lower sedentary time, while residential density, pedestrian infrastructure and safety and lack of barriers to walking were related to higher sedentary time. Aesthetics and safety from crime were related to less sedentary time in women only. In contrast, few cul-de-sacs, land use – access, land use – diversity, connectivity and traffic safety were not significantly associated.

In the multiple environmental-variable model, all of those environmental correlates remained statistically significant with the exception of safety from crime. Additionally, after adjustment for other perceived environmental correlates, land use mix–diversity was found to be related to less sedentary time in men only (Table 3). Associations of perceived environmental attributes with objectively-measured sedentary time did not significantly differ by study site.

INSERT TABLE 3ABOUT HERE

Associations of a composite environmental index with sedentary time

The attributes found to be significant in the multiple-environmental model (perceived residential density, pedestrian infrastructure and safety, no major barriers to walking, land use mix – diversity, street connectivity, aesthetics, and safety from crime) were used to derive a composite environmental index based on the sum of the standardized values (z-scores) of each variable, as detailed in the Methods section. This index was positively related to objectively-assessed sedentary time (Table 3). Each additional unit on the index was associated with 3.4 min/day more sedentary time. The association was stronger in women than in men (Table 3), with women showing 4.5 more min/day and men 2.0 more min/day of sedentary time for each one-unit increment in the composite environmental index. The predicted difference in sedentary time between those with the minimum (-9.2) and maximum (11.6) values on the composite environmental index was 71 min/day of sedentary time.

DISCUSSION

Across all 12 countries, 59% of time on average was spent sedentary, which ranged from 56% (Colombia and Hong Kong) to 64% (Denmark). The difference in average sedentary time between the least and most sedentary countries was some 70 min/day, reflecting a wide range of variation in sedentary time.

Our findings showed both expected and unexpected associations. The interpretation of these findings is challenging, not the least because sedentary behaviors take place not only in neighborhood environments, but at home, in motor vehicles and at work. Those living in areas with higher connectivity or with better aesthetics had less sedentary time. However, it is notable that two destination-related measures, (land use mix – diversity and land use mix – access), which are often associated with walking, were not related to sedentary time (except for diversity with men's sedentary time). It is possible that residents in such areas may spend less time at home and in cars, and more time outdoors in other leisure pursuits. It should be noted in this context that accelerometer-assessed sedentary time does not perfectly reflect sitting time (32) and that some of light-intensity PA (strolling) or standing may have been misclassified as sedentary time.

We found associations of higher residential density with more sedentary time. Given that higher residential density is typically associated with higher levels of physical activity, it was anticipated that density would be negatively associated with sedentary time. Residents of lower density areas are likely to have fewer public transport options and therefore could be expected to spend more time in cars and less time in active transport. A potential explanation of this unexpected finding is that residents of higher density areas may in some cases be better educated or of higher socio-economic status, which can be associated with more sedentary time; particularly work-related sitting (33). Further research examining domain-specific sedentary behavior – particularly distinguishing work, leisure and transport sitting – is needed to clearly explain why residential density can be associated with overall sedentary time.

Leisure time availability as a pathway in the associations of neighborhood environments with sedentary time may be applicable to other (unexpected) findings. For example, those who have better infrastructure (sidewalks, street lights, crossing for pedestrians) may live in inner-urban areas, where significantly less commuting time to places of employment (hence, longer leisure time) may be required. This may in part also account for the association of having no barriers to walking with longer sedentary time.

While a strength of this study is the objective measurement of sedentary behavior, a limitation is that we were unable to examine the specific correspondence between the contexts in which sedentary behaviors take place (particularly domestic and workplace environments) and the neighborhood environments to which our exposure measures related. Environmental attributes may influence only certain sedentary behaviors such as driving or TV time (17). Although non-workers were less than a quarter of the overall study sample, they are a subgroup who would be more likely to spend longer time in their neighborhoods and thus may display a stronger correspondence between neighborhood environment attributes and their sedentary time.

The environmental attributes were assessed using a previously-developed self-report instrument with known measurement properties (11, 12, 15). Further examination of these relationships using objective measures derived from Geographic Information System databases (34) is needed, both to confirm the present findings and to examine relationships with other potentially relevant environmental attributes. To provide more targeted evidence for particular environmental and urban design policy initiatives, the separation of sedentary time measures into domain-specific components would be highly informative. For example, home-based sedentary time, time spent sitting in cars and occupational sitting are likely to have distinct environmental correlates, which will require domain-specific measurement of the potentially-relevant environmental exposures and sedentary behaviors in those contexts.

We identified built environment attributes associated with adults' sedentary behavior, including street connectivity, land use mix and aesthetics, which have also been found to be related to physical activity. If appropriate environmental enhancements were to be implemented, there may be benefits not only through increased levels of participation in physical activity, but also through reducing the adverse health consequences of sedentary time.

REFERENCES

1. Chau JY, Grunseit AC, Chey T, Stamatakis E, Brown WJ, Matthews CE, et al. Daily sitting time and all-cause mortality: a meta-analysis. PLoS One 2013;8(11):e80000.
2. Thorp AA, Healy GN, Owen N, Salmon J, Ball K, Shaw JE, et al. Deleterious associations of sitting time and television viewing time with cardiometabolic risk biomarkers - Australian Diabetes, Obesity and Lifestyle (AusDiab) study 2004-2005. Diabetes Care 2010;33(2):327-334.
3. Healy GN, Dunstan DW, Salmon J, Cerin E, Shaw JE, Zimmet PZ, et al. Objectively measured light-intensity physical activity is independently associated with 2-h plasma glucose. Diabetes Care 2007;30(6):1384-9.
4. Matthews CE, Chen KY, Freedson PS, Buchowski MS, Beech BM, Pate RR, et al. Amount of time spent in sedentary behaviors in the United States, 2003-2004. Am J Epidemiol 2008;167(7):875-81.
5. Owen N, Sparling PB, Healy GN, Dunstan DW, Matthews CE. Sedentary behavior: emerging evidence for a new health risk. Mayo Clin Proc 2010;85(12):1138-41.
6. Sallis JF CE, Conway TL, Adams MA, Frank LD, Pratt M, Salvo D, Schipperijn J, Smith G, Cain KL, Davey R, Kerr J, Lai P-C, Mitas J, Reis R, Sarmiento OL, Schofield G, Troelsen J, Van Dyck D, De Bourdeaudhuij I, Owen N. . Urban environments in 14 cities worldwide are related to physical activity. The Lancet 2016;387(10034):2207-2217.
7. Giles-Corti B SJ, Sugiyama T, Frank L, Lowe M, Owen N. Translating active living research into policy and practice: One important pathway to chronic disease prevention. Journal of Public Health Policy 2015;36(2):231-243.
8. Van Cauwenberg J, De Donder L, Clarys P, De Bourdeaudhuij U, Owen N, Dury S, et al. Relationships of individual, social, and physical environmental factors with older adults' television viewing time. J Aging Phys Act 2014;22(4).
9. Barnett A, Cerin E, Ching CS, Johnston JM, Lee RS. Neighbourhood environment, sitting time and motorised transport in older adults: a cross-sectional study in Hong Kong. BMJ Open 2015;5(4):e007557.
10. Strong LL, Reitzel LR, Wetter DW, McNeill LH. Associations of perceived neighborhood physical and social environments with physical activity and television viewing in African-American men and women. Health Promotion 2013;27(6):401-409.
11. Cerin E, Conway TL, Saelens BE, Frank LD, Sallis JF. Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and its abbreviated form (NEWS-A). Int J Behav Nutr Phys Act 2009;6(1):32.
12. Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environment scale evaluation. American journal of public health 2003;93(9):1552-1558.
13. Van Dyck D, Cerin E, Conway TL, De Bourdeaudhuij I, Owen N, Kerr J, et al. Associations between perceived neighborhood environmental attributes and adults' sedentary behavior: findings from the USA, Australia and Belgium. Social science & medicine 2012;74(9):1375-1384.
14. Koohsari MJ, Sugiyama T, Sahlqvist S, Mavoa S, Hadgraft N, Owen N. Neighborhood environmental attributes and adults' sedentary behaviors: review and research agenda. Preventive medicine 2015;77:141-149.
15. Cerin E, Conway TL, Cain KL, Kerr J, De Bourdeaudhuij I, Owen N, et al. Sharing good NEWS across the world: developing comparable scores across 12 countries for the

neighborhood environment walkability scale (NEWS). BMC public health 2013;13(1):309.
16. Van Dyck D, Cardon G, Deforche B, Owen N, Sallis JF, De Bourdeaudhuij I. Neighborhood walkability and sedentary time in Belgian adults. American Journal of Preventive Medicine 2010;39(1):25-32.
17. Kozo J, Sallis JF, Conway TL, Kerr J, Cain K, Saelens BE, et al. Sedentary behaviors of adults in relation to neighborhood walkability and income. Health Psychol 2012;31(6):704-13.
18. Owen N. Ambulatory monitoring and sedentary behaviour: a population-health perspective. Physiological measurement 2012;33(11):1801.
19. Kerr J, Sallis JF, Owen N, De Bourdeaudhuij I, Cerin E, Sugiyama T, et al. Advancing science and policy through a coordinated international study of physical activity and built environments: IPEN adult methods. J Phys Act Health 2013;10(4):581-601.
20. Cerin E, Leslie E, Owen N, Bauman A. An Australian version of the Neighborhood Environment Walkability Scale: validity evidence. Meas Phys Educ Exerc Sci 2008;12(1):31-51.
21. Frank LD, Sallis JF, Saelens BE, Leary L, Cain K, Conway TL, et al. The development of a walkability index: application to the Neighborhood Quality of Life Study. Br J Sports Med 2010;44(13):924-33.
22. Cain K. Accelerometer Scoring Protocol for the IPEN-Adult Study. University California San Diego, CA: University California San Diego, CA; 2013.
23. Freedson P, Miller K. Objective monitoring of physical activity using motion sensors and heart rate. Research quarterly for exercise and sport 2000;71(2 Suppl):S21-9.
24. Welk GJ. Use of accelerometry-based activity monitors to assess physical activity. In: Physical activity assessments for health-related research; 2002. p. 125-141.
25. Cerin E, Cain KL, Conway TL, Van Dyck D, Hinckson E, Schipperijn J, et al. Neighborhood environments and objectively measured physical activity in 11 countries. Med Sci Sports Exerc 2014;46(12):2253-64.
26. Freedson PS, Melanson E, Sirard J. Calibration of the Computer Science and Applications, Inc. accelerometer. Medicine and science in sports and exercise 1998;30(5):777-781.
27. Wood S. Generalized additive models: an introduction with R: CRC press; 2006.
28. Burnham KP, Anderson DR. Model selection and multimodel inference: a practical information-theoretic approach. 2nd ed. New York: Springer Science & Business Media; 2002.
29. Harrell F. Regression Modeling Strategies: With Applications to Linear Models, Logistic Regression and Survival Analysis: New York, NY: Springer-Verlag; 2001.
30. Fox J, Weisberg S. An R companion to applied regression. 2nd ed ed: Sage. Thousand Oaks CA; 2011.
31. Warnes G. gmodels: Various R programming tools for model fitting; 2012.
32. Healy GN, Clark BK, Winkler EA, Gardiner PA, Brown WJ, Matthews CE. Measurement of adults' sedentary time in population-based studies. American journal of preventive medicine 2011;41(2):216-227.
33. Mielke GI, da Silva IC, Owen N, Hallal PC. Brazilian adults' sedentary behaviors by life domain: population-based study. PLoS One 2014;9(3):e91614.
34. Adams MA, Frank LD, Schipperijn J, Smith G, Chapman J, Christiansen LB, et al. International variation in neighborhood walkability, transit, and recreation environments using geographic information systems: the IPEN adult study. Int J Health Geogr 2014;13(1):43.

Table 1. Overall and site-specific sample characteristics

	ALL SITES	BEL	BRA	COL	CZE		DEN	HK	MEX	ESP	UK	USA	
					Site A	Site B						Site C	Site D
Overall N[1]	5712	1050	330	223	258	122	272	269	656	329	135	1198	870
Age, mean (SD)	43 (12)	43 (13)	42 (13)	46 (12)	39 (14)	36 (14)	40 (14)	42 (13)	42 (13)	39 (13)	44 (13)	44 (11)	47 (11)
Gender, *%men*	47	48	48	32	36	39	39	41	46	40	47	55	49
Education													
%Less than HS	14	4	28	47	23	16	7	36	44	4	39	1	2
%HS graduate	33	33	31	36	43	57	42	23	29	33	46	35	30
%College or more	52	63	41	17	33	28	50	41	27	63	15	64	69
Work status, *%working*	77	80	79	61	78	83	75	63	71	76	64	81	83
Marital Status, *%couple*	63	73	60	61	60	53	69	56	65	57	46	64	61
BMI, mean (SD)	25.7 (4.9)	24.2 (3.9)	26.2 (4.3)	25.5 (4.1)	24.6 (3.9)	24.2 (3.6)	24.2 (4.0)	22.6 (3.4)	28.0 (5.0)	23.9 (3.4)	27.2 (5.1)	26.6 (5.4)	27.2 (5.7)
Accelerometer wear time, valid days (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)	6.5 (0.8)	6.6 (1.0)	6.7 (0.8)	6.7 (1.2)
Accelerometer wear time, hr/day (SD)	14.5 (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)	15.0 (1.1)	14.6 (1.2)	14.7 (1.3)	14.8 (1.4)
Sedentary time, min/day (SD)	512.9 (105.1)	507.1 (109.8)	475.6 (111.5)	462.9 (92.2)	486.5 (101.3)	508.1 (95.0)	571.8 (90.5)	542.4 (97.8)	467.8 (89.8)	543.8 (87.7)	499.1 (104.4)	523.5 (103.7)	537.5 (102.2)
MVPA time, min/day (SD)	36.3 (25.4)	35.5 (23.5)	31.5 (24.6)	37.0 (26.4)	47.1 (27.7)	45.1 (25.9)	39.7 (23.3)	44.9 (25.3)	31.2 (25.2)	51.0 (29.5)	36.7 (27.3)	36.3 (24.9)	29.2 (22.0)

Notes: [1] N for some variables is reduced due to missing data. Site A: Olomouc, B: Hradec Kralove, C: Seattle, D: Baltimore. Accelerometer wear time, valid days = total number of valid days of 10+ wearing hours. Accelerometer wear time, hr/day= average number of valid hours per valid day. Sedentary time, min/day= average minutes of sedentary per valid day. Moderate-vigorous physical activity (MVPA) time, min/day= average minutes of moderate-to-vigorous physical activity per valid day. Missing values: age (0.2%), gender (0%), education (1%), work status (0.2%), marital status (1%), BMI (0.9%)

Table 2. Overall and site-specific perceived-environment scores

	All SITES	BEL	BRA	COL	CZ		DEN	HK	MEX	ESP	UK	USA	
					Site A	Site B						Site C	Site D
Overall N[1]	5712	1050	330	223	258	122	272	269	656	329	135	1198	870
Residential density (SD)	86.9 (122)	82.6 (72.4)	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)	187.0 (102.3)	36.2 (32.5)	37.5 (53.9)	59.9 (79.4)
Land use mix-Access (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)	3.7 (0.5)	3.4 (0.7)	3.2 (0.8)	3.0 (0.8)
Connectivity (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)	3.3 (0.7)	3.1 (0.7)	3.0 (0.8)	3.0 (0.8)
Infrastructure and safety (SD)	3.0 (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)	3.4 (0.5)	3.2 (0.5)	3.0 (0.6)	3.1 (0.6)
Aesthetics (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)	2.7 (0.7)	2.3 (0.8)	3.1 (0.7)	3.1 (0.6)
Safety from traffic (SD)	2.6 (0.7)	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)	2.5 (0.7)	2.5 (0.7)	2.7 (0.7)	2.7 (0.7)
Safety from crime (SD)	3.1 (0.8)	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 (0.70	2.2 (0.7)	3.6 (0.6)	3.0 (0.7)	3.4 (0.6)	3.4 (0.7)
Few cul-de-sacs (SD)	2.9 (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)	3.6 (0.9)	2.3 (1.0)	2.8 (1.1)	2.8 (1.2)
No major barriers (SD)	3.3 (0.9)	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)	3.6 (0.8)	3.4 (0.8)	3.2 (1.0)	3.8 (0.6)
Land use mix - diversity (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)	4.5 (0.4)	3.7 (0.5)	3.8 (0.8)	3.6 (0.9)
Composite index of sedentariness (SD)	0.0 (2.6)	0.0 (2.6)	-0.6 (2.6)	-0.2 (1.5)	1.2 (1.9)	1.2 (1.9)	1.2 (1.9)	3.8 (3.1)	-1.4 (1.7)	2.5 (2.1)	0.7 (2.0)	-1.0 (2.2)	-0.3 (2.1)

Notes: [1] N for some variables is reduced due to missing data. Site A: Olomouc, B: Hradec Kralove, C: Seattle, D: Baltimore. Land use mix-Diversity = Land Use Mix-Diversity: Proximity to 9 places-categories. Missing values: Residential density (2.2%), Land use mix-Access (0.7%), Connectivity (0.8%), Infrastructure and safety (0.8%), Aesthetics (0.8%), Safety from traffic (0.8%), Safety from crime (0.8%), Few cul-de-sacs (0.8%), No major barriers (0.8%), Land use mix - diversity (0.6%). Composite index of sedentariness (2.2%).

Table 3. Pooled associations of perceived environmental attributes with objectively-measured sedentary time (average daily minutes)

Environmental attribute	Effect	Single-environmental-attribute models			Multiple-environmental-attribute models		
		b	95% CI	p	b	95% CI	p
Residential density	Main	0.078	0.053, 0.105	<.001	0.075	0.048, 0.102	<.001
Land use mix –access	Main	3.029	-0.301, 6.342	.08	1.156	-2.747, 5.059	.56
Land use mix – diversity	Main	1.588	-1.532, 4.709	.32	-1.593	-5.169, 1.983	.38
	Men-specific	-	-	-	-5.293	-9.839, -0.747	.02
	Women-specific	-	-	-	1.662	-2.641, 5.965	.45
Connectivity	Main	1.925	-4.963, 1.113	.22	-4.719	-8.051, -1.467	<.01
Pedestrian infrastructure and safety	Main	8.287	4.464, 12.109	<.001	8.300	4.026, 12.575	<.001
Aesthetics	Main	-3.316	-6.844, 0.211	.07	-4.294	-7.915, -0.672	.02
	Men-specific	2.765	-2.066, 7.595	.26	2.129	-2.748, 7.005	.39
	Women-specific	-7.936	-12.268, -3.604	<.001	-9.127	-13.535, -4.719	<.001
Traffic safety	Main	1.873	-1.431, 5.178	.27	2.507	-0.986, 6.000	.16
Safety from crime	Main	-0.171	-3.798, 3.455	.93	0.144	-3.600, 3.888	.94
	Men-specific	4.281	-0.370, 8.932	.07	-	-	-
	Women-specific	-3.782	-8.608, -0.044	<.05	-	-	-
Few cul-de-sacs	Main	1.563	-0.698, 3.824	.17	1.471	-0.785, 3.728	.20
No major barriers to walking	Main	3.561	0.947, 6.174	<.01	2.928	0.236, 5.620	.03
Composite environmental index	Main	3.354	2.363, 4.345	<.001	-	-	-
	Men-specific	1.990	0.663, 3.318	<.01	-	-	-
	Women-specific	4.483	3.255, 5.711	<.001	-	-	-

b = regression coefficient; 95% CI = 95% confidence intervals; p = p value; - = not applicable. All regression coefficients are adjusted for respondents' age, sex, marital status, educational attainment, employment status, administrative-unit socio-economic status, average objectively-measured min/day of moderate-to-vigorous physical activity and accelerometer wear time. For environmental attributes with significant gender moderating effects, gender-specific associations (men- and women-specific) are reported.