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Associations between perceived neighborhood environmental attributes and adults' sedentary behavior: Findings from the USA, Australia and Belgium

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Abstract

Sedentary behaviors are associated with multiple health problems, independently of physical activity. Neighborhood environment attributes might influence sedentary behaviors, but few studies have investigated these relationships. Moreover, all previous studies have been conducted within single countries, limiting environmental variability. We investigated the shape of associations between perceived neighborhood environment attributes and sedentary behavior in three countries; and whether these associations differed by country and gender. Data from USA (Seattle and Baltimore regions), Australia (Adelaide) and Belgium (Ghent) were pooled. Data collection took place between 2002 and 2008. In total, 6,014 adults (20–65 years, 55.7% women) were recruited in high-/low-walkability and high-/low-income neighborhoods. All participants completed the International Physical Activity Questionnaire (domain-specific physical activity, transport-related sitting and overall time spent sitting) and the Neighborhood Environmental Walkability Scale (environmental perceptions). The number of destinations within a 20 minute walk from home, perceiving few cul-de-sacs, good walking and cycling facilities, and traffic safety were included in an index of motorized transport correlates. This index was linearly

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negatively associated with motorized transport time, so the higher the scores on the index (more activity-friendliness), the lower the amount of motorized transport. No gender- or country-differences were identified. Perceived aesthetics and proximity of destinations were included in an index of overall sitting time correlates. A linear negative relationship with overall sitting time was found, but associations were stronger for men and not significant in Belgian adults. In conclusion, consistent and expected correlates were found for motorized transport in the three countries, but results were less clear for overall sitting time. Future studies should include even more countries to maximize environmental variability, but present findings suggest that neighborhoods may be designed to improve health through supporting more active and less sedentary transportation, which can be expected to have health benefits.

Keywords

sitting; NEWS; built environment; dose-response; pooled analyses; USA, Australia; Belgium

INTRODUCTION

There is a strong international consensus that approaches to physical activity (PA) promotion should intervene on multiple levels, targeting psychological factors, physical and social environments, and policy factors (WHO, 2004), as informed by ecological models (Sallis et al., 2006). Reviews have identified a consistent relationship between objectively-assessed and perceived built environment characteristics and PA for transportation and recreation purposes, but almost exclusively for adults living in developed countries (Gebel et al., 2007; Heath et al., 2006; Owen et al., 2004; Wendel-Vos et al., 2007). Some of the correlates usually associated with active transport are walkability attributes, like residential density, street connectivity, land use mix. Active recreation is usually related to access to recreation facilities, neighborhood aesthetics, and traffic safety, with crime-related safety having inconsistent findings.

Recent studies have documented associations of sedentary behaviors (including overall sitting time, television viewing time, and time spent sitting in cars) with health problems such as obesity, metabolic syndrome and mortality; these associations are independent of the level of PA (Dunstan et al., 2010; Frank et al., 2004; Healy et al., 2008; Katzmarzyk et al., 2009; Owen et al., 2010). It is important to note that sedentary behavior is not a synonym of physical inactivity (i.e. lack of physical activity), nor the opposite of physical activity. Physical activity and sedentary behavior can coexist; individuals may engage in sufficient physical activity, but still spend the rest of their day in sedentary behaviors (Owen et al., 2010). While it is possible that neighborhood environment attributes independently influence sedentary behaviors, few studies have reported on relationships of the built environment with sedentary time.

A USA study found objectively-assessed neighborhood walkability attributes to be negatively associated with time spent sitting in cars (Frank et al, 2004). Other USA results showed that prolonged TV viewing in adults was related to perceived negative aspects of the neighborhood environment, including heavy traffic and crime, lack of neighborhood lighting and poor scenery (King et al., 2010). An Australian study found similar results, reporting that women living in highly-walkable neighborhoods spent less time watching TV than women living in less-walkable neighborhoods (Sugiyama et al., 2007). No association was found for men. In contrast, a Belgian study found that highly-walkable neighborhood residents spent more time being sedentary compared to those living in less-walkable neighborhoods (Van Dyck et al., 2010a). These conflicting results justify additional research to clarify the nature of the associations between built environment attributes and sedentary time. Moreover, most previous studies examined the associations of neighborhood walkability attributes with sedentary time, so including a wider variety of built and social environmental characteristics would be useful to more fully understand the associations. Some studies have suggested that the built environment may affect the behavior of men and women in different ways (Shibata et al., 2009; Spence et al., 2006; Sugiyama et al., 2007), warranting further exploration.

Almost all studies on built-environment attributes, PA and sedentary behaviors have been conducted within single countries. Since the within-country variability in environmental attributes and PA-related behaviors is likely to be limited, this may have resulted in underestimation of the strength of the associations of built environment factors with PA and sedentary time. We have identified only one study included common methods across countries, making it possible to conduct pooled analyses (Sallis et al., 2009a). Those multi-country findings showed that associations between perceived environmental attributes and PA were stronger compared to what had been reported in single-country studies. Moreover, a linear gradient was found in the relationship: the more supportive the perceived neighborhood environment attributes were (e.g. higher availability of sidewalks and bicycle facilities, more land use mix), the more likely individuals were to be sufficiently physically active (Sallis et al., 2009a). However, we found no studies that have used multi-country data to investigate the strength of the associations between the built environment and sedentary time.

To identify potential associations between built environment attributes and sedentary time and to obtain a better estimation of the strength and shape of these associations, data from three countries (USA, Australia, and Belgium) using common measures and protocols were examined. The present study investigated the shape of associations (dose-response) between perceived neighborhood environment attributes and sedentary time (overall sitting and motorized transport time); and, whether these associations differed by country, study site and gender. The dose-response pattern of the associations was examined to find out whether sedentary time progressively decreases with increasing activity-friendliness of the environment (linear association) or whether certain environmental 'thresholds' need to be crossed before associations with sedentary time can be found (curvilinear association). Furthermore, overall sitting and motorized transport time were included as distinct outcome measures because ecological models of health behaviors emphasize the behavior-specificity of correlates. Probably, correlates of overall sitting time are different compared with correlates of motorized transport time.

METHODS

Procedures and Participants

Data from three countries were pooled for present analyses: USA (Neighborhood Quality of Life Study [NQLS] in Seattle-King County and Baltimore-Washington DC regions), Australia (Physical Activity in Localities and Community Environments [PLACE] study in Adelaide), and Belgium (Belgian Environmental Physical Activity Study [BEPAS] in Ghent). Data were therefore collected in four study sites (two in the USA, one in Australia, and one in Belgium). Detailed information on the protocols, procedures and other results of these three studies can be found elsewhere (Owen et al., 2007; Sallis et al., 2009b; Van Dyck et al., 2010b).

Briefly, in each country, participants (20–65 year old adults) were recruited in high- and low-walkability and high- and low-income neighborhoods (32 neighborhoods in NQLS and PLACE; 24 neighborhoods in BEPAS). The neighborhoods were chosen to maximize within-country variance in walkability and income. In all countries, neighborhoods consisted of clusters of administrative units (block groups in USA; Census Collectors' Districts in Australia; statistical sectors in Belgium). These administrative units were the smallest geographical units for which information on income and other demographic factors was available.

Neighborhood-level walkability was determined objectively, using a Geographic Information Systems (GIS) based walkability index, including three (BEPAS) or four (NQLS and PLACE) environmental attributes previously found to be related to PA (Frank et al., 2010): net residential density, land use mix, intersection density, and retail floor area ratio. Retail floor area ratio was omitted in BEPAS, because no GIS data were available for this variable. A detailed description of the calculation of the walkability index is given elsewhere (Frank et al, 2010). To determine neighborhood-level income, census-based median annual household income data (National Institute of Statistics – Belgium 2007; Australian Bureau of Statistics – Australia 2001; U.S. Census 2000) were used. The neighborhood selection procedure resulted in an equal number of neighborhoods (n=8 for NQLS and PLACE; n=6 for BEPAS) among four types, stratified as follows: high-walkability/high-income, high-walkability/low-income, low-walkability/high-income, and low-walkability/low-income.

In the USA, NQLS data collection took place between May 2002 and June 2005. In total, 8,504 adults living in the 32 neighborhoods were randomly selected from lists supplied by a marketing company, contacted by phone and mailed a survey if they agreed to participate. In total, 2,199 participants completed the mailed survey (response rate = 25.9%; 1,287 participants in Seattle and 912 participants in Baltimore). Response rates did not differ significantly by study quadrant (range from 23% to 29%). Compared with USA census data (U.S. Census 2000), the study sample was older, had fewer women, more whites, fewer Hispanics and higher household incomes. In Australia, PLACE data collection was conducted between July 2003 and June 2004. A simple random sampling procedure was used to select possible participants within the 32 selected neighborhoods. Invitation letters and surveys were mailed to these possible participants. In total, 2,650 of the 23,128 contacted adults returned a completed survey (response rate = 11.5%). The response rate ranged from 10.5% in the low-SES neighborhoods to 12.8% in the high-walkability, high-SES neighborhoods. Response rates did not differ significantly by study quadrant. Compared with Australian census data (Australian Bureau of Statistics – Australia 2001), study participants were more likely to be older, female, and in paid work. In Belgium, BEPAS data collection took place between May 2007 and September 2008. In each neighborhood, 250 randomly selected adults received an invitation letter and were visited at home two-to-six days after posting the letter. Recruitment continued until 50 participants per neighborhood were recruited (response rate = 58.0%); 1,165 adults participated in BEPAS. Response rates did not differ significantly by study quadrant (range from 57.5% to 58.7%). Compared with Belgian census data (National Institute of Statistics – Belgium), participants were more likely to be highly educated and employed. In all studies, data were collected throughout the year to take seasonal variation into account.

All participants completed a written informed consent form. NQLS was approved by Institutional Review Boards at participating academic institutions, PLACE was approved by the Behavioral and Social Sciences Ethics Committee of the University of Queensland, and BEPAS was approved by the Ethics Committee of the Ghent University Hospital.

Measures

Environmental perceptions—To measure perceived neighborhood built and social environmental factors, the Dutch and English versions of the previously validated Neighborhood Environmental Walkability Scale (NEWS) were used (Cerin et al., 2009; De

Bourdeaudhuij et al., 2003; Saelens et al., 2003). Before data analysis, comparability of the NEWS items across the three countries was assessed by two independent raters. Based on these ratings, only the comparable NEWS items (40 out of 68) were included in the present analyses. Included neighborhood environment scales were residential density (5 items), land use mix diversity (12 items), land use mix access (3 items), street connectivity (2 items), walking and cycling facilities (6 items), aesthetics (3 items), traffic safety (3 items), and crime safety (3 items). The following were used as single items: ‘parking is difficult near local shopping areas’, ‘there are many barriers in my neighborhood which make it difficult to walk from one place to the other’, and ‘streets in my neighborhoods do not have many cul-de-sacs’. Calculation of the NEWS scales and selection of the three single items were based on methods proposed by Cerin and colleagues (2009) after a cross-validation of the confirmatory factor analysis structure of NEWS. All items that were comparable across countries were included in their respective scales. All environmental factors were rated on a four-point scale, except for residential density and land use mix access (five-point scales). Site-specific descriptive statistics of the NEWS scales can be found in Table 1.

PA and sitting time—Self-reported PA and sitting time were measured with the International Physical Activity Questionnaire (IPAQ; long past seven days version). PA assessed by the IPAQ has good reliability (intra-class correlations range from .46 to .96) and fair-to-moderate criterion validity compared against accelerometers (median ρ=.30) in a 12-country study (Craig et al., 2003). Frequency (number of days in the last seven days) and duration (minutes/day) of PA in different domains (work-related and leisure-time walking, moderate PA and vigorous PA; household-related moderate and vigorous PA; transport-related walking and cycling) were queried. Based on the time spent doing PA in the different domains, min/week of total PA was calculated with no weighting for intensity. Sitting time assessed by the IPAQ has good reliability (intra-class correlations range from .40 to 1.0) and fair criterion validity compared against accelerometers (most Spearman correlations >.25) in a three-country study (Rosenberg et al., 2008). Overall daily minutes spent sitting (excluding transport-related sitting time) and frequency and duration of motorized transportation in the past seven days were assessed. In Belgium, the interviewer-administered version of IPAQ was used, while in Australia and USA, participants completed the self-administered version.

Socio-demographic information—Self-reported socio-demographic variables included gender, age, marital status (partner vs. no partner), educational level (college/university degree vs. no college/university degree), height, weight, having a driver’s license (yes/no), and number of drivable vehicles in the household. These factors have been associated with sedentary behaviors in previous studies (Clark et al., 2010; Stamatakis et al., 2003; Vandelanotte et al., 2009; Van Dyck et al., 2010a; Van Dyck et al., 2010b).

Data analytic plan

Descriptive statistics (mean, standard deviations, percentages, medians and interquartile ranges, and percentage of missing values) were computed by study site for all outcome variables, socio-demographic covariates and explanatory variables. Generalized additive mixed models (GAMMs) with appropriate variance (negative binomial) and link functions (logarithmic) were used to estimate the strength and shape of the associations of perceived environmental attributes with average daily minutes of overall sitting time and weekly minutes of motorized transport time (Wood, 2006). The shape of dose-repose relationships was estimated using thin plate splines, which tend to perform better than other smoothing methods (Wood, 2006). Smoothing methods are used to estimate dose-response relationships of unknown shape which, due to their unknown nature, cannot be a priori defined with parametric functions. Random intercepts were specified to account for clustering in the data, i.e., respondents were sampled from selected neighborhoods. A first set of models estimated the dose-response relationships of single perceived environmental attributes with the two outcomes, adjusting for socio-demographic covariates and study site. Separate models were run to estimate main effects of environmental attributes, two-way gender by environmental attributes and study site by environmental attributes interaction effects, and three-way gender by study site by environmental attribute interaction effects. The significance of interaction effects was evaluated by comparing the Akaike Information Criteria (AIC) of the main- versus interaction-effects models (a lower AIC is indicative of a better model) (Wood, 2006).

All perceived environmental attributes that yielded main and/or interaction effects significant at a 0.15 probability level were included in a multiple-predictor model of overall sitting or motorized transport time. All variables and interaction terms that remained significant at that level were retained in a final multiple-predictor model (Tabachnick & Fidell, 2007). We adopted a 0.15 probability level because the findings from this study were based only on data from three Western countries and, thus, from an international perspective, are still somewhat exploratory. It is possible that some of the environmental features that were only weakly correlated with the outcomes might show stronger relationships in other geographical locations or other samples. These variables were also used to construct a composite environmental index for each outcome variable. This was done by summing up the standardized scores (z-scores) of the variables that were negatively related and subtracting the standardized scores of variables that were positively related to the outcome. Thus, we created two composite indices, one representing an environmental index of factors associated with less overall sitting time and the other representing an environmental index of factors associated with less motorized transport. The dose-response relationships of the indices with the relative outcomes were estimated using GAMMs in the same manner as for the single environmental attributes (see above).

Approximately 30% of the cases had missing values on at least one of the variables. Data were assumed to be missing at random (the likelihood of having missing data on specific variables was unrelated to socio-demographic, site, perceived environmental, or/and outcome variables) rather than missing completely at random (likelihood of missing data unrelated to any measured or unmeasured variable) (Rubin, 1987). Therefore, 10 multiple imputed datasets were created (10 is the recommended number of imputations for obtaining robust results; Rubin, 1987). Imputations were performed using chained equations whereby separate models were constructed for each variable with missing values (depending on their level of measurement and distributional assumptions; Raghunathan et al., 2001). The variables entered in each model were those involved in the planned analyses. All analyses were conducted on complete cases and three imputed datasets containing the average, lowest and highest imputed values for missing data. Although the point estimates of the regression coefficients were similar across the datasets (0% to 3% difference), multiple imputations yielded narrower confidence intervals (8%–25% difference). Thus, we present the results of the analyses based on average imputed values. All analyses were conducted in R (R Development Core Team, 2011) using the packages 'car' (Fox and Weisberg, 2011), 'mgcv' (Wood, 2006), and 'Design' (Harrell, 2009).’

RESULTS

Table 1 reports the descriptive statistics (site characteristics, socio-demographics, sedentary behaviors and PA, and perceived environmental attributes) for each study site. In total 6,014 participants were included in the analyses. Of the total sample, 55.7% were women, 63.3% were living with a partner, 55.4% had tertiary education and 91.6% had a driver’s license. In Belgium, a higher percentage of participants (73.0%) reported living with a partner. In Baltimore and Seattle regions, more participants had a driver’s license (95.6% and 94.4%), while in Australia, fewer participants completed tertiary education (45.5%). Mean age of the total sample was 44.4 yrs (SD=11.9), mean body mass index (BMI) was 26.1 kg/m^2 (SD=5.5) and the average minutes/week of total PA was 1216.0 (SD=917.7). BMI and minutes/week of total PA were lower in Belgian participants compared with USA and Australian adults.

Socio-demographic correlates of overall sitting and motorized transport time

Table 2 reports the associations of socio-demographic covariates with average daily minutes of overall sitting and weekly minutes of motorized transport. Belgian participants reported significantly higher amounts of time spent sitting than their American and Australian counterparts but lower amounts of motorized transport than American respondents. Australian respondents also reported significantly lower levels of motorized transport than their American counterparts. Being a women, being older, living in higher income areas and with a partner, having a driver’s license, lower BMI and no University degree were predictive of lower levels of overall time spent sitting. Being a woman, being older, having a lower BMI and not having a driver’s license were predictive of less time spent in motorized transport.

Dose-response associations between perceived physical environmental attributes and overall sitting time

Main effects models of overall sitting with single environmental attributes as predictors (adjusted for socio-demographic confounders) supported positive associations with residential density and negative associations with number of different types of destinations (a measure of land use mix-diversity), access to services (land use mix-access) and aesthetics (Table 3). For example, a unit difference on the aesthetics scale was associated with 3.0% (95% CI: 1.2%, 4.8%) less average daily minutes spent sitting (p=.001). Gender was a significant moderator of the relationships with the three land use mix and the two safety variables (see single environmental attribute models with interaction effects in Table 3). Specifically, while the associations of land use mix with sitting were not significant in women, they were linearly negative in men. Crime safety and traffic safety were unrelated to sitting in men but were linearly negatively related in women. Significant interaction effects were also observed for study site by crime and traffic safety on sitting, whereby negative associations were found only in Australian respondents. These associations were linear rather than curvilinear.

In a model adjusted for all perceived environmental attributes showing at least weak independent associations with sitting (i.e. with a p-value <.15; see model with multiple environmental variables and interaction terms in Table 3), these site interaction effects were no longer significant. However, the gender by land use mix and crime safety interaction effects remained significant, as did the main effects of perceived residential density and aesthetics.

An index of factors associated with less overall sitting time was constructed based on the above findings. The index consisted of the sum of the standardized scores (z-scores) of perceived environmental attributes independently negatively related (overall or in a subgroup of the sample) to overall sitting (aesthetics, land use mix diversity and proximity to destinations) minus the standardized scores of the perceived attribute independently positively related to overall sitting (residential density). Attributes showing significant opposite effects in subgroups of the sample were excluded (i.e., crime safety). Overall, the index was linearly negatively related to overall sitting and negatively related to overall sitting in all study sites with the exception of Ghent (Belgium). This association was stronger in men than in women (last model in Table 3).

Dose-response associations between perceived physical environmental attributes and motorized transport time

Higher levels of perceived land use mix-diversity, walking and cycling facilities, traffic safety, and the absence of cul-de-sacs were all associated with less time in motorized transport in main effect models with single environmental attributes as predictors (Table 4). For example, a unit difference on the 'walking and cycling facilities' scale was associated with a 3.9% (95% CI: 1.3%, 6.4%) lower average weekly minutes of motorized transport (p=.004). The effects of land use mix were curvilinear (see Figure 1; panels A and B). Steeper declines in motorized transport were observed for average proximity scores higher than 3, corresponding to distances within a 20min walk (Figure 1, panel A). Steep declines in motorized transport were also observed for reports of over 10 types of destinations within a 20 min walk from home (Figure 1, panel B). The latter dose-response relationship was observed in women only (Figure 1; panel C). In men, the effect of number of destinations within 20min walking distance on motorized transport was not significant (Table 4; models with interaction effects). Only one other significant interaction effect on motorized transport was observed; the negative association of traffic safety with motorized transport time was significant in Australian respondents only (Table 4; single environmental attribute models with interaction effects).

The inclusion of all significant main and interaction effects in a model of motorized transport time with multiple environmental predictors resulted in a final model encompassing main effects of lack of cul-de-sacs, traffic safety, walking and cycling facilities, and number of different types of destinations within 20min walk from home (a land use mix-diversity measure; Figure 1, panel D) (Table 4; model with multiple environmental attributes and interaction effects). None of the interaction effects remained significant. Lack of cul-de-sacs and more different types of destinations were the strongest predictors of less time sitting in motorized transport.

An index representing environmental correlates of motorized transport consisting of the sum of the standardized scores (z-scores) of perceived environmental attributes independently negatively related to time spent in motorized transport (land use mix-diversity, number of different types of destinations within 20min walk from home; absence of cul-de-sacs; traffic safety; and walking and cycling facilities) was constructed. Overall, the index was linearly negatively related to motorized transport time so that a unit difference in the index (observed range; −10 to 5) was predictive of 8.1% (95% CI: 5.6%, 10.7%) fewer weekly minutes of motorized transport. The estimated difference in minutes of motorized transport between the lowest and highest scoring respondents on this index was 71.8% ($1–0.919^{15}$ =0.718); i.e., as compared to the lowest scoring participants, highest scoring participants reported 71.8% fewer weekly minutes of motorized transport.

DISCUSSION

These dose-response associations between physical environmental perceptions and sedentary behaviors (overall self-reported sitting time and motorized transport time) in adults were derived by combining data from three environmentally- and culturally-diverse countries in pooled analyses. After controlling for socio-demographic covariates, the findings revealed consistent and expected associations between neighborhood environmental attributes and motorized transport time, while the associations were somewhat less clear for overall sitting time, which is a more-generic measure that presumably includes a number of sedentary behaviors within different contexts. Moreover, for sitting during motorized transport, results were comparable across countries and genders, but for overall sitting, the comprehensive model was only significant in the Australian and USA samples and the associations were stronger in men than in women.

Number of destinations within a 20 min walk from home, perceiving few cul-de-sacs, good walking and cycling facilities, and traffic safety were included in a composite index of correlates of motorized transport. Comparing participants across the full range of the index, those living in the most activity-supportive neighborhoods reported about 70% less time in motorized transport than their peers living in the least activity-supportive neighborhoods. The ability to detect these associations is probably in part attributable to the broader range of environmental variation in this international study compared with studies using data from a single geographical site. Present results are similar with previous studies showing objectively-assessed walkability parameters such as connectivity and land use mix were negatively associated with motorized transportation (Frank et al., 2004; Van Dyck et al., 2010b). Moreover, perceptions of mixed land use, connectivity, walking and cycling facilities and traffic safety have been consistently associated with active transportation in adults (Cerin et al., 2006; De Bourdeaudhuij et al., 2005; Owen et al., 2004; Saelens & Handy, 2008; Shigematsu et al., 2009; Van Dyck et al., 2011), so positive perceptions of these environmental attributes might influence adults to partially replace their motorized transportation with more-active modes of transportation.

The composite model provided evidence of a linear gradient in the association with motorized transport time, so the more supportive the environment, the less time a participant used motorized transport. However, the multiple predictor model showed a curvilinear relationship between land use mix diversity and motorized transport. When more than 10 destinations were available within a 20min walk, a steep decrease in the amount of motorized transport was observed. This finding suggests that for some environmental perceptions, a ‘threshold’ needs to be crossed before positive associations with health behaviors can be observed. This information can be useful in developing evidence-based guidelines for the design of highly-walkable neighborhoods. For future research, including more countries with even more variability in environmental characteristics (e.g., African or Asian countries) would further clarify the shape of these dose-response relationships and lead to more specific international guidelines for highly-walkable communities.

For overall sitting time, the associations were less consistent. The environmental index of factors associated with less overall sitting time consisted of perceived aesthetics and proximity of destinations (measure of land use mix), but it had to be corrected for residential density, since density was positively but unexpectedly related to overall sitting. The positive association between residential density and sitting time was found in all countries, and no unequivocal explanation is apparent. Usually, residential density is considered a component of walkability and is positively related to PA (Bauman & Bull, 2007; Saelens & Handy, 2008), so density was expected to be inversely related to sitting time. In the sites studied, perhaps high residential density indicated lower socioeconomic status that may be related to more sedentary leisure time such as television viewing. There is no strong correlation between time spent sitting and time devoted to motor transportation ($r=0.017$; $p=0.479$) so it does not seem to be the case that more time taken for motor transport in less walkable areas leaves less time for other sendentary activities. Further research is needed to explain the role of perceived residential density in sitting time, especially in multiple domains (e.g. leisure time, household; Owen et al., 2011).

Overall, the index was linearly related with overall sitting time, supporting the potential role of positive perceptions of aesthetics and the proximity of destinations in reducing total sitting time. Surprisingly, this association was only significant in USA and Australian adults. The descriptive statistics showed that the mean values of perceived land use mix and aesthetics were lower in Belgian participants compared with their American and Australian counterparts, while the mean values for residential density were higher. Consequently, it seems that Belgium is located at the lower-end of the environmental variability spectrum for these perceptions, which might explain the absence of an overall association with sitting time in the Belgian subsample. European cities are typically found to be denser than those in USA and Australia (Newman & Kenworthy, 1991), so present results could suggest systematic biases in reporting that differ by country.

The perceived neighborhood environment attributes examined in this study were less strongly associated with overall sitting than motorized transport time. A partial explanation for this finding could be that the NEWS questionnaire was primarily developed to examine environmental correlates of active transportation and not of overall sitting time (Saelens et al., 2003). Overall sitting can occur in multiple life domains of leisure, household, and occupation, and each of these is likely to have distinct environmental correlates (Owen et al., 2011). Some gender-specific results were found, but present findings were fairly consistent across men and women. The present results also supported the behavioral specificity of environmental attributes. The characteristics that were related to motorized transport differed from those associated with overall sitting time. Previous researchers emphasized the importance of behavior-specific research to fully understand the underlying mechanisms of health behaviors (Giles-Corti et al., 2005; Owen et al., 2004; Owen et al., 2011; Saelens et al., 2003; Saelens & Handy, 2008). The present results support these models. Behavior-specific research may help develop evidence-based intervention strategies for the multiple domains and settings of sedentary behavior.

Creating an index from individual environmental attributes instead of examining single environmental attributes led to stronger associations with the outcomes. This pattern was also found by Sallis and colleagues (2009a) in a study examining the relationship between perceived environmental attributes and PA in 11 countries. Evidence is accumulating that the cumulative effects of multiple environmental attributes are likely needed to influence sedentary behaviors and PA, and no single over-riding environmental correlate has been identified. Continued research could be oriented to identify optimal combinations or patterns of built and social environment correlates of behaviors that may generalize across populations and perhaps countries.

Belgian adults reported more total sitting time than their American and Australian counterparts, while American respondents reported more time in motorized transport. The higher amounts of overall sitting time in Belgians might be attributed to the assessment mode of the IPAQ. In Belgium, the interview version of the IPAQ was used, while the self-administered version was used in Australia and the USA. Previous research has shown that adults tend to over-report their PA levels when filling out the self-administered IPAQ (Rzewnicki et al., 2003). Because individuals tend to over-report socially desirable behavior and under-report socially undesirable behaviors (Nunally, 1978), sitting time will likely be under-reported. Recall bias can also play a role. The presence of a trained researcher, who prompts the participant and tries to prevent socially-desirable behaviors, can help reduce under-reporting of sitting time. American respondents had the highest levels of motorized transport. This is not surprising, since distances between destinations are often very long in the USA.

Present results help resolve some apparently-contradictory findings from the few previous neighborhood environment-sedentary time studies, two of which were based on studies used in present analyses (Sugiyama et al., 2007; Van Dyck et al., 2010a). Of particular interest were unexpected findings that neighborhood walkability was positively related to total sitting time in the Belgian sample (Van Dyck et al., 2010a). The pattern was somewhat replicated in the present study with an environmental index of correlates of overall sitting time not related to total sitting time among Belgians but inversely related to total sitting time among Americans and Australians. Reasons for the country differences were not clear.

Much more consistent results across countries were found with neighborhood environment correlates of motorized transport time. One implication is that more specific sedentary behavior outcomes may produce more consistent environmental correlates.

A primary strength of the present study was the assessment of large samples of adults in three environmentally and culturally diverse countries, creating larger variability in environmental characteristics than one study site could provide. Within-country environmental variability was maximized by recruiting participants from the highest- and lowest-walkability neighborhoods of each study site. Secondly, perceived environmental attributes and sedentary time were measured using valid and reliable questionnaires. However, some challenges and limitations emerged when conducting this three-country study. First, since small cultural (specifically European) adaptations were applied to the NEWS questionnaire in Belgium, only a limited number of comparable environmental items could be included in analyses. Further, interpretations of NEWS items could vary by country. Second, use of the interviewer-administered IPAQ in Belgium and the self-administered version in Australia and the USA could have biased the results. Third, a cross-sectional design was used, which precluded determination of causality. Fourth, the relatively low response rates in the USA and Australia potentially could have introduced selection bias. Although within-country response rates were similar across study quadrants, this could have a significant impact on the variability of the environmental perceptions and time spent being sedentary. The response rate was higher in the Belgian study, probably because participants were visited at home instead of receiving a mailed survey (Portney & Watkins, 2009).

In conclusion, we found that perceived environmental attributes (land use mix-diversity, walking and cycling facilities, traffic safety and few cul-de-sacs) were associated with less motorized transport time, across three countries. One apparent threshold was identified, with less motorized transport among residents of neighborhoods with 10 or more types of destinations within a 20 minute walk. A neighborhood environment index closely related to walkability indexes (Frank et al., 2010) was associated with 70% less time spent in motorized transport among those in the most walkable neighborhoods. Thus, neighborhood attributes that have been consistently and positively related to transport-related walking were strongly and inversely related to less motorized transport time in three countries. Present findings suggest that neighborhoods can be designed that may improve health through supporting more active transportation and less sedentary time associated with sitting in automobiles, which can be expected to have independent health benefits (Owen et al., 2010).

RESEARCH HIGHLIGHTS

- Data from culturally and environmentally diverse countries were pooled to examine environment – sedentary time associations
- Several interactions with gender and study site (country) were identified for overall sitting time.
- Behavior-specific dose-response associations led to the construction of indices containing important sedentary correlates
- Consistent correlates of motorized transport were revealed, which can help to design activity-friendly neighborhoods.

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REFERENCE LIST

Australian Bureau of Statistics. [access verified on December 7, 2011] Census of Population and Housing: CDATA 2001, CD-ROM, Final Release. ABS. Available online at: www.abs.gov.au

Bauman, AE.; Bull, FC. [access verified on December 7, 2011] Environmental correlates of physical activity and walking in adults and children: a review of reviews. Review undertaken for National Institute Health and Clinical Excellence. 2007. Available on: www.nice.org.uk/nicemedia/live/11679/34741/34741.doc

Cerin E, Conway TL, Saelens BE, Frank LD, Sallis JF. Cross-validation of the factorial structure of the Neighborhood Environment Walkability Scale (NEWS) and it abbreviated form (NEWS-A). International Journal of Behavioral Nutrition and Physical Activity. 2009; 6:32. [PubMed: 19508724]

Cerin E, Saelens B, Sallis JF, Frank LD. Neighborhood environment walkability scale: validity and development of a short form. Medicine & Science in Sports & Exercise. 2006; 38:1682–1691. [PubMed: 16960531]

Clark BK, Sugiyama T, Healy GN, Salmon J, Dunstan DW, Shaw JE, et al. Socio-demographic correlates of prolonged television viewing time in Australian men and women: the AusDiab study. Journal of Physical Activity & Health. 2010; 7:595–601. [PubMed: 20864754]

Craig CL, Marshall AL, Sjöström M, Bauman AE, Booth ML, Ainsworth BE, et al. International Physical Activity Questionnaire-12-country reliability and validity. Medicine & Science in Sports & Exercise. 2003; 35:1381–1395. [PubMed: 12900694]

De Bourdeaudhuij I, Sallis JF, Saelens BE. Environmental correlates of physical activity in a sample of Belgian adults. American. Journal of Health Promotion. 2003; 18:83–92.

De Bourdeaudhuij I, Teixeira PJ, Cardon G, Deforche B. Environmental and psychosocial correlates of physical activity in Portuguese and Belgian adults. Public Health Nutrition. 2005; 8:886–895. [PubMed: 16277805]

Dunstan DW, Barr ELM, Healy GN, Salmon J, Shaw JE, Balkau B, et al. Television viewing time and mortality: The Aus Diab study. Circulation. 2010; 121:384–391. [PubMed: 20065160]

Frank LD, Andresen MA, Schmid TL. Obesity relationships with community design, physical activity, and time spent in cars. American Journal of Preventive Medicine. 2004; 27:87–96. [PubMed: 15261894]

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. British Journal of Sports Medicine. 2010; 44:924–933. [PubMed: 19406732]

Fox, J.; Weisberg, S. An R Companion to applied regression. Second Edition. Thousand Oaks CA: Sage; 2011.

Gebel K, Bauman AE, Petticrew M. The physical environment and physical activity: a critical appraisal of review articles. American Journal Preventive Medicine. 2007; 32:361–369.

Giles-Corti B, Timperio A, Bull F, Pikora T. Understanding physical activity environmental correlates: increased specificity for ecological models. Exercise and Sport Sciences Reviews. 2005; 33:175–181. [PubMed: 16239834]

Harrell, FE. Design: Design Package. R package version 2.3-0. 2009. http://CRAN.R-project.org/package=Dproject.org/package=Design

Healy GN, Dunstan DW, Salmon J, Shaw JE, Zimmet PZ, Owen N. Television time and continuous metabolic risk in physically active adults. Medicine & Science in Sports & Exercise. 2008; 40:639–645. [PubMed: 18317383]

Heath G, Brownson R, Kruger J, Miles R, Powell KE, Ramsey LT. the Task Force on Community Preventive Services. The effectiveness of urban design and land use and transport policies and practices to increase physical activity: a systematic review. Journal of Physical Activity & Health. 2006; 3:S55–S76.

Katzmarzyk PT, Church TS, Craig CL, Bouchard C. Sitting time and mortality from all causes, cardiovascular disease, and cancer. Medicine & Science in Sports & Exercise. 2009; 41:1998–2005.

King AC, Goldberg JH, Salmon J, Owen N, Dunstan D, Weber D, et al. Identifying subgroups of US adults at risk for prolonged television viewing to inform program development. American Journal of Preventive Medicine. 2010; 38:17–26. [PubMed: 20117553]

National Institute of Statistics – Belgium. [Access verified on December 7, 2011] www.statbel.fgov.be, FOD Economie – Algemene Directie Statistiek. 2007.

Newman PW, Kenworthy JR. Transport and urban form in thirty-two of the world's principal cities. Transport Reviews. 1991; 11:249–272.

Nunnally, JC. Psychometric Theory. 2nd ed. New York: McGraw-Hill; 1978.

Owen N, Cerin E, Leslie E, duToit L, Coffee N, Frank LD, et al. Neighborhood walkability and the walking behavior of Australian adults. American Journal of Preventive Medicine. 2007; 33:387–395. [PubMed: 17950404]

Owen N, Healy GN, Mathews CE, Dunstan DW. Too much sitting: the population-health science of sedentary behavior. Exercise and Sport Sciences Reviews. 2010; 38:105–113. [PubMed: 20577058]

Owen N, Humpel N, Leslie E, Bauman A, Sallis JF. Understanding environmental influences on walking: review and research agenda. American Journal of Preventive Medicine. 2004; 27:67–76. [PubMed: 15212778]

Owen N, Sugiyama T, Eakin EE, Gardiner PA, Tremblay MS, Sallis JF. Adults' sedentary behavior: determinants and interventions. American Journal of Preventive Medicine. 2011; 41:189–196. [PubMed: 21767727]

Portney, LG.; Watkins, MP. Foundations of clinical research: Applications to practice. 3rd edition. New Jersey: Pearson Education, Inc.; 2009. p. 325-357.

Raghunathan TE, Lepkowski JM, Van Hoewyk J, Solenberger P. A multiple technique for multiply imputing missing values using a sequence of regression models. Survey Methodology. 2001; 27:85–95.

R Development Core Team. R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing; 2009. ISBN 3-900051-07-0, URL http://www.R-project.org/

Rosenberg DE, Bull FC, Marshall AL, Sallis JF, Bauman AE. Assessment of sedentary behavior with the International Physical Activity Questionnaire. Journal of Physical Activity & Health. 2008; 5:S30–S44. [PubMed: 18364524]

Rubin, DB. Multiple imputation for non-response in surveys. New York: Wiley J & Sons; 1987.

Rzewnicki R, Vanden Auweele Y, De Bourdeaudhuij I. Addressing overreporting on the International Physical Activity Questionnaire (IPAQ) telephone survey with a population sample. Public Health Nutrition. 2003; 6:299–305. [PubMed: 12740079]

Saelens BE, Handy SL. Built environment correlates of walking: a review. Medicine & Science in Sports & Exercise. 2008; 40:S550–S566. [PubMed: 18562973]

Saelens BE, Sallis JF, Black JB, Chen D. Neighborhood-based differences in physical activity: an environmental scale evaluation. American Journal of Public Health. 2003; 93:1552–1558. [PubMed: 12948979]

Saelens BE, Sallis JF, Frank LD. Environmental correlates of walking and cycling: findings from the transportation, urban design, and planning literatures. Annals of Behavioral Medicine. 2003; 25:80–91. [PubMed: 12704009]

Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J. An ecological approach to creating more physically active communities. Annual Review of Public Health. 2006; 27:297–322.

Sallis JF, Bowles HR, Bauman AE, Ainsworth BE, Bull FC, Craig CL, et al. Neighborhood environments and physical activity among adults in 11 countries. American Journal of Preventive Medicine. 2009a; 36:484–490. [PubMed: 19460656]

Sallis JF, Saelens BE, Frank LD, Conway TL, Slymen DJ, Cain KL, et al. Neighborhood built environment and income: examining multiple health outcomes. Social Science & Medicine. 2009b; 68:1285–1293. [PubMed: 19232809]

Shibata A, Oka K, Harada K, Nakamura Y, Muraoka I. Psychological, social and environmental factors to meeting physical activity recommendations among Japanese adults. International Journal of Behavioral Nutrition and Physical Activity. 2009; 6:60. [PubMed: 19715568]

Shigematsu R, Sallis JF, Conway TL, Saelens BE, Frank LD, Cain KL, Chapman JE, King AC. Age differences in the relation of perceived neighborhood environment to walking. Medicine & Science in Sports & Exercise. 2009; 41:314–321. [PubMed: 19127195]

Spence JC, Plotnikoff RC, Rovniak LS, Martin Ginis KA, Rodgers W, Lear SA. Perceived neighbourhood correlates of walking among participants visiting the Canada on the move website. Canadian Journal of Public Health. 2006; 97:S39–S44. 2006.

Stamatakis E, Hillsdon M, Mishra G, Hamer M, Marmot M. Television viewing and other screen-based entertainment in relation to multiple socioeconomic status indicators and area deprivation: the Scottish Health Survey. Journal of Epidemiology & Community Health. 2003; 63:734–740. [PubMed: 19401278]

Sugiyama T, Salmon J, Dunstan D, Bauman AE, Owen N. Neighborhood walkability and TV viewing time among Australian adults. American Journal of Preventive Medicine. 2007; 33:444–449. [PubMed: 18022059]

Tabachnick, BG.; Fidell, LS. Using multivariate statistics. 5th edition. Boston: Allyn and Bacon; 2007. p. 140

Vandelanotte C, Sugiyama T, Gardiner P, Owen N. Associations of leisure-time Internet and computer use with overweight and obesity, physical activity and sedentary behaviors: cross-sectional study. Journal of Medical Internet Research. 2009; 11:e28. [PubMed: 19666455]

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. 2010a; 39:25–32. [PubMed: 20547277]

Van Dyck D, Cardon G, Deforche B, Sallis JF, Owen N, De Bourdeaudhuij I. Neighborhood SES and walkability are related to physical activity behavior in Belgian adults. Preventive Medicine. 2010b; 50:S74–S79. [PubMed: 19751757]

Van Dyck D, Cardon G, Deforche B, Giles-Corti B, Sallis JF, Owen N, et al. Environmental and psychosocial correlates of accelerometer-assessed and self-reported physical activity. International Journal of Behavioral Medicine. 2011; 18:235–245. [PubMed: 21038103]

Wendel-Vos W, Droomers M, Kremers S, Brug J, van Lenthe F. Potential environmental determinants of physical activity in adults: a systematic review. Obesity Reviews. 2007; 8:425–440. [PubMed: 17716300]

Wood, SN. Generalized additive models: an introduction with R. Boca Raton, Florida: Chapman & Hall; 2006.

World Health Organization (WHO). Global strategy on diet, physical activity and health: Report by the Secretariat. Geneva: 2004.

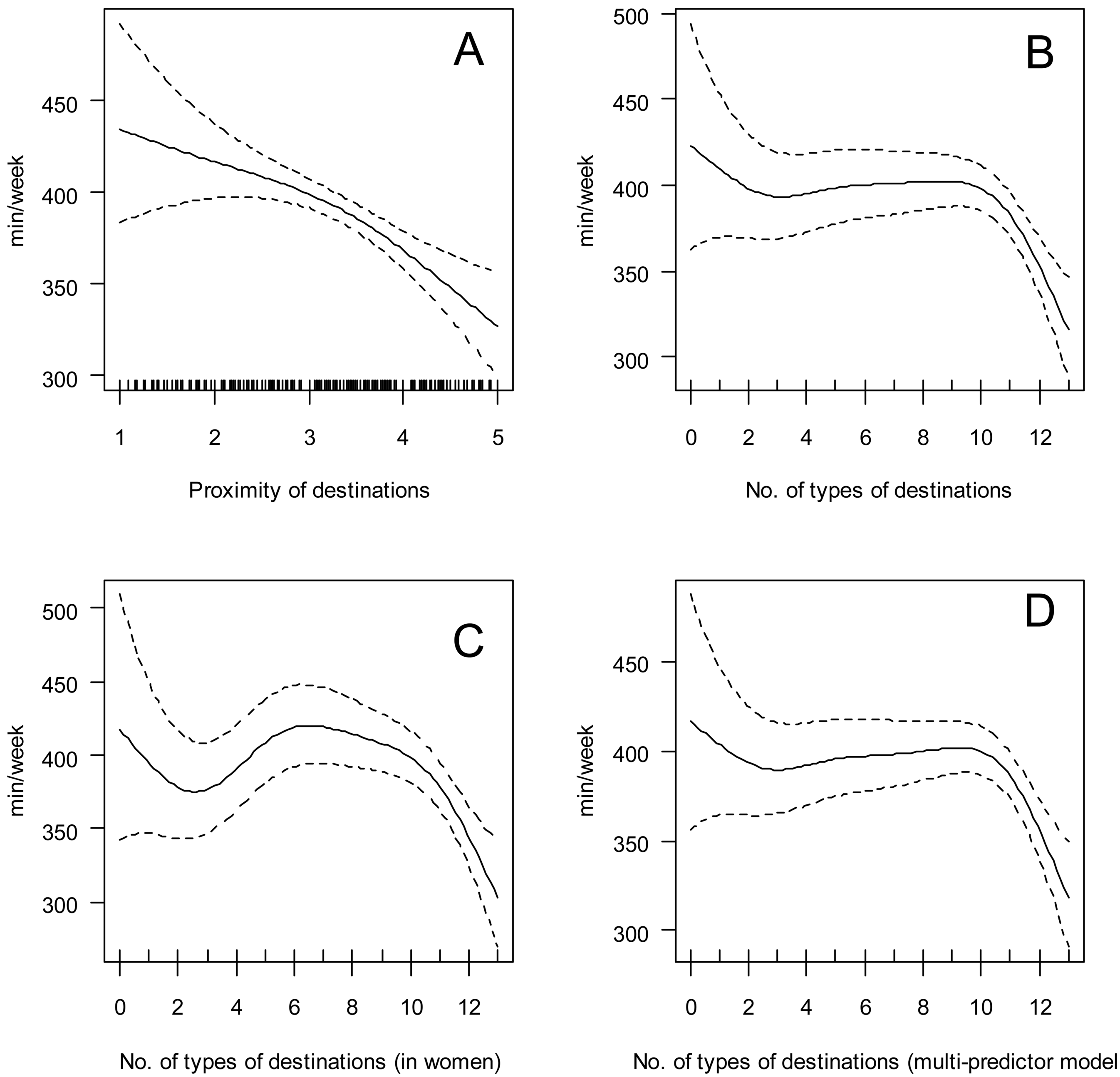

Figure 1.
Dose-response relationship of land use mix diversity measures and weekly minutes of motorized transport

Table 1

Site-specific descriptive statistics for all outcome variables, socio-demographic covariates and explanatory variables

	Seattle region – USA (n=1,287)	Baltimore region – USA(n=912)	Adelaide – Australia (n=2650)	Ghent – Belgium (n=1,165)
Site characteristics				
Number of inhabitants	1,916 441	5,699,478	1,289,265	248,269
Area (km^2)	5,506	25,210	1,827	156.2
Population density (inhabit/km^2)	348.1	226.1	1,295	1,589
Mean temperature January (°C)	4.5	2.7	23.1	3.1
Mean temperature July (°C)	18.4	27.6	11.4	17.7
Average precipitation/year (mm)	944.6	1065.3	500.0	820.0
High walkability areas participants (%)	50.6	49.2	48.6	50.0
High income areas participants (%)	51.3	52.5	52.2	50.5
Area level household income (mean [SD])	USD 56,680 (19,912.2)	USD 59,930 (21,758.3)	AUD 38,080 (12,966.0)	EU19,610.0 (3,967.2)
Sociodemographic characteristics				
Gender - % women	45.1	52.3	63.7	52.0
Age (mean [SD])	44.0 (11.0)	46.6 (10.7)	44.5 (12.3)	42.7 (12.6)
Marital status - % with partner	63.1	60.1	60.3	73.0
Education - % tertiary education	63.0	67.2	45.5	60.3
Driver’s license - % with license	95.6	94.4	89.2	90.2
Number of drivable vehicles(mean [SD])	2.0 (1.2)	1.9 (1.1)	1.6 (1.0)	1.6 (1.1)
Body mass index (mean [SD])	26.6 (5.5)	27.2 (5.9)	26.2 (5.9)	24.3 (3.9)
Sedentary time and physical activity (mean [SD])				
Min/week of total physical activity	1086.8 (765.3)	1115.1 (811.9)	1519.3 (1047.6)	802.1 (587.4)
Min/day of overall sitting time	365.0 (175.8)	364.8 (179.1)	373.9 (290.7)	421.4 (157.8)
Min/week of motorized transport	478.6 (386.5)	554.1 (398.7)	354.2 (379.0)	326.7 (306.0)
Perceived physical environmental attributes (mean [SD])				
Residential density	140.5 (49.6)	156.4 (58.2)	143.5 (46.1)	187.9 (72.2)
Land use mix-diversity – proximity of destinations	3.3 (0.8)	3.1 (0.9)	3.4 (0.7)	3.0 (0.9)
Land use mix-diversity - # destinations within 20min walk	8.2 (2.8)	7.5 (3.1)	9.2 (3.1)	7.2 (3.3)
Land use mix-access	3.2 (0.8)	3.0 (0.8)	3.5 (0.7)	3.1 (0.6)
Street connectivity	3.0 (0.8)	3.0 (0.8)	3.0 (0.7)	2.8 (0.6)
Walking and cycling facilities	2.9 (0.7)	3.1 (0.6)	3.0 (0.5)	2.7 (0.5)
Aesthetics	3.2 (0.7)	3.2 (0.6)	3.2 (0.7)	2.5 (0.6)
Traffic safety	3.0 (0.7)	3.1 (0.7)	2.7 (0.7)	2.4 (0.6)
Crime safety	3.4 (0.6)	3.4 (0.7)	3.0 (0.8)	3.1 (0.6)

	Seattle region – USA (n=1,287)	Baltimore region – USA(n=912)	Adelaide – Australia (n=2650)	Ghent – Belgium (n=1,165)
Parking difficult near local shopping areas	1.9 (1.0)	1.8 (0.9)	2.0 (1.0)	2.5 (0.9)
Not many barriers in neighborhood	3.2 (1.0)	3.7 (0.6)	3.6 (0.6)	3.3 (0.7)
Not many cul-de-sacs	2.8 (1.1)	2.8 (1.2)	2.8 (1.1)	3.0 (0.8)

SD = standard deviation; USD = United Stated Dollar; AUD = Australian dollar; EU = Euro

Note: all perceived environmental attributes were positively scored: higher score = more walkable

Table 2

Associations of socio-demographic covariates with sitting time (average min/day) and motorized transport time (min/week)

	Sitting (average min/day)			Motorized transport (min/wk)		
Variables	**exp(*b*)**	**exp (95% CI)**	***p***	**exp(*b*)**	**exp (95% CI)**	***p***
Area-level household income (deciles)	0.993	0.987, 0.999	.035	0.998	0.985, 1.011	.795
Gender (Men vs. Women)	0.959	0.929, 0.990	.011	0.869	0.828, 0.913	<.001
Age (yrs)	0.998	0.997, 0.999	.029	0.993	0.991, 0.995	<.001
Marital status (without vs. with partner)	0.945	0.914, 0.977	<.001	1.008	0.958, 1.061	.750
Tertiary education (no vs. yes)	1.077	1.042, 1.114	<.001	0.979	0.929, 1.032	.440
Holder of a driver's license (no vs. yes)	0.949	0.910, 0.988	.012	1.359	1.237, 1.493	<.001
Body mass index (kg/m^2)	1.006	1.005, 1.006	<.001	1.010	1.006, 1.015	<.001
Study site (reference category: Ghent, Belgium)						
Seattle, USA	0.868	0.822, 0.918	<.001	1.399	1.233, 1.586	<.001
Baltimore, USA	0.857	0.810, 0.910	<.001	1.642	1.445, 1.866	<.001
Adelaide, Australia	0.909	0.866, 0.954	<.001	1.067	0.958, 1.187	.241

Note. Associations are adjusted for all other socio-demographic covariates. All regression models used a negative binomial variance function and a logarithmic link function. Exp(*b*) antilogarithm of regression coefficient; exp(95% CI) = antilogarithms of the 95% confidence intervals of the regression coefficient; p = probability value. The antilogarithms of the regression coefficients represent the proportional increase (if exp(b) > 1.00) or decrease (if exp(b)<1.00) in the outcome variables associated with a unit increase in an explanatory variable.

Table 3

Associations of perceived environmental attributes with sitting time (average min/day)

Variables	exp(*b*)	exp (95% CI)	*p*
<u>Models with single environmental attributes</u>			
Main effects			
Residential density	1.026	1.008, 1.044	.008
Land use mix-diversity – proximity of destinations	0.986	0.969, 1.002	.089
Land use mix-diversity – # destinations within 20min walk	0.983	0.967, 0.999	.044
Land use mix-access	0.981	0.965, 0.998	.027
Not many cul-de-sacs	1.000	0.984, 1.015	.963
Parking difficult near local shopping areas	1.012	0.996, 1.029	.144
Not many barriers in neighborhood	1.004	0.983, 1.026	.696
Street connectivity	0.993	0.977, 1.009	.384
Walking and cycling facilities	0.987	0.971, 1.004	.128
Aesthetics	0.970	0.952, 0.988	.001
Traffic safety	0.990	0.973, 1.008	.276
Crime safety	0.989	0.971, 1.006	.207
Significant Interaction effects			
Gender by Land use mix-diversity – proximity of destinations			
Association in men	0.957	0.934, 0.980	<.001
Association in women	1.010	0.989, 1.032	.356
Gender by Land use mix-diversity - # destinations within 20min walk			
Association in men	0.957	0.934, 0.981	<.001
Association in women	1.002	0.980, 1.023	.852
Gender by Land use mix-access			
Association in men	0.962	0.939, 0.985	.002
Association in women	0.998	0.976, 1.020	.841
Gender by Traffic safety			
Association in men	1.013	0.987, 1.039	.334
Association in women	0.976	0.955, 0.997	.025
Gender by Crime safety			
Association in men	1.024	0.997, 1.052	.078
Association in women	0.967	0.946, 0.989	.003
Site by Traffic safety			
Associations in Ghent, Belgium	1.020	0.977. 1.065	.373
Associations in Seattle, USA	1.001	0.975, 1.045	.579
Associations in Baltimore, USA	0.988	0.946, 1.032	.592
Associations in Adelaide, Australia	0.972	0.949, 0.996	.025
Site by Crime safety			
Associations in Ghent, Belgium	1.016	0.970. 1.064	.502
Associations in Seattle, USA	1.024	0.984, 1.064	.238
Associations in Baltimore, USA	0.974	0.933, 1.016	.217

Variables	exp(*b*)	exp (95% CI)	*p*
Associations in Adelaide, Australia	0.975	0.953, 0.998	.035
Model with multiple environmental attributes and interaction effects*			
Residential density	1.034	1.015, 1.053	<.001
Aesthetics	0.961	0.951, 0.987	.001
Gender by Land use mix-diversity – proximity of destinations			
Association in men	0.953	0.930, 0.977	<.001
Association in women	1.002	0.980, 1.025	.863
Gender by Crime safety			
Association in men	1.032	1.004, 1.060	.021
Association in women	0.977	0.955, 0.999	.040
Models with composite environmental indices of factors associated with less overall sitting time			
Index (=Land use mix-diversity + proximity of destinations + Aesthetics − Residential density)	0.954	0.935, 0.971	<.001
Gender by Index interaction effect			
Association in men	0.943	0.919, 0.968	<.001
Association in women	0.961	0.939, 0.984	<.001
Site by Index interaction effect			
Associations in Ghent, Belgium	0.982	0.944, 1.022	.388
Associations in Seattle, USA	0.960	0.923, 0.998	.039
Associations in Baltimore, USA	0.950	0.910, 0.992	.020
Associations in Adelaide, Australia	0.935	0.907, 0.964	<.001

Note. All models were adjusted for gender, age, living arrangements (with vs. without partner), driver's license holder (yes vs. no), tertiary education (yes vs. no), area household income (in deciles), body mass index, study site. All regression models used a negative binomial variance function and a logarithmic link function. Only significant interaction effects are presented. Exp(*b*) antilogarithm of regression coefficient; exp(95% CI) = antilogarithms of the 95% confidence intervals of the regression coefficient; *p* = probability value;

* final model including only predictors significant at p<.15. The antilogarithms of the regression coefficients represent the proportional increase (if exp(b) > 1.00) or decrease (if exp(b)<1.00) in average min/day of sitting associated with a unit increase in a perceived environmental attribute.

Table 4

Associations of perceived environmental attributes with motorized transport time (min/week)

Variables	exp(*b*)	exp (95% CI)	*p*
Models with single environmental attributes			
Main effects			
Residential density	0.994	0.964, 1.025	.704
Land use mix-diversity – proximity of destinations (linear)	0.932	0.877, 0.991	.024
Land use mix-diversity – proximity of destinations (curvilinear smooth) *	F(1.72)=8.01		<.001
Land use mix-diversity – # destinations within 20min walk	0.788	0.655, 0.948	.012
Land use mix-diversity – # destinations within 20min walk (curvilinear smooth) *	F(3.91)=5.22		<.001
Land use mix-access	0.974	0.897, 1.057	.523
Not many cul-de-sacs	0.946	0.923, 0.969	<.001
Parking difficult near local shopping areas	0.997	0.971, 1.024	.820
Not many barriers in neighborhood	0.973	0.923, 1.026	.317
Street connectivity	0.983	0.957, 1.010	.212
Walking and cycling facilities	0.961	0.936, 0.987	.004
Aesthetics	0.996	0.911, 1.089	.937
Traffic safety	0.971	0.944, 0.999	.047
Crime safety	0.989	0.971, 1.006	.207
Significant Interaction effects			
Gender by Land use mix-diversity - # destinations within 20min walk			
Association in men (linear term only)	0.970	0.933, 1.010	.137
Association in women (linear)	0.738	0.574, 0.949	.018
Association in women (curvilinear smooth) *	F(4.06)=4.91		<.001
Site by Traffic safety			
Associations in Ghent, Belgium	0.999	0.931, 1.072	.985
Associations in Seattle, USA	0.970	0.918, 1.025	.283
Associations in Baltimore, USA	0.970	0.800, 1.175	.757
Associations in Adelaide, Australia	0.959	0.923, 0.997	.036
Model with multiple environmental attributes and interaction effects *			
Land use mix-diversity – # destinations within 20min walk	0.786	0.650, 0.951	.013
Land use mix-diversity – # destinations within 20min walk (curvilinear smooth) *	F(4.01)=4.10		.003
Not many cul-de-sacs	0.949	0.926, 0.972	<.001
Walking and cycling facilities	0.977	0.950, 1.004	.104
Traffic safety	0.979	0.953, 1.006	.141
Model with composite environmental index of factors associated with less motorized transport			
Index (=Land use mix-diversity, # of destinations + Not many cul-de-sacs + Walking and cycling facilities + Traffic safety)	0.919	0.834, 0.944	<.001

Note. All models were adjusted for gender, age, living arrangements (with vs. without partner), driver's license holder (yes vs. no), tertiary education (yes vs. no), area household income (in deciles), body mass index, study site. All regression models used a negative binomial variance function and a logarithmic link function. Only significant interaction effects are presented. Exp(*b*) antilogarithm of regression coefficient; exp(95% CI) = antilogarithms of the 95% confidence intervals of the regression coefficient; *p* = probability value;

*final model including only predictors significant at p<.15. The antilogarithms of the regression coefficients represent the proportional increase (if exp(b) > 1.00) or decrease (if exp(b)<1.00) in min/wk of motorized transport associated with a unit increase in a perceived environmental attribute.