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ORIGINAL ARTICLE

Neighbourhood environment and transport-related and leisure-time sedentary behaviour amongst women in a city in Southern Brazil: a multilevel analysis

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Abstract

Objectives To assess the association between neighbourhood environmental variables and excessive transport-related and leisure-time sedentary behaviour (ETSB and ELSB, respectively) amongst adult women in Southern Brazil.

Methods A cross-sectional survey was conducted using a representative sample of 1079 women 20 to 69 years of age who lived in 44 neighbourhoods. Each neighbourhood was determined by drawing a 400-m buffer around the median point of the participants' homes. Neighbourhoods were assessed by audit and by using government data. Sedentary behaviour (SB) and the remaining individual variables were assessed via questionnaire that was administered as an interview. Multilevel logistic regression analysis was conducted.

Results In the adjusted analysis, women who lived in neighbourhoods with a higher percentage of terrain slope and fewer public recreation areas per resident had significantly ($p \leq 0.05$) increased odds of exhibiting ETSB and ELSB, with 50% and 40% increases, respectively.

Conclusions The results show that some aspects of the neighbourhood environment such as terrain slope and total public recreation areas per resident are related to specific SBs, indicating that improvements in neighbourhoods can reduce SB in women.

Keywords Sedentary behaviour · Environment · Neighbourhood · Women

Introduction

Sedentary behaviour (SB) is defined as activities performed in a sitting or lying posture under conditions of reduced energy expenditure (≤ 1.5 metabolic equivalents) (Sedentary Behaviour Research 2012). In recent years, prospective studies have shown a correlation between time spent in SB and the risk of diabetes, cardiovascular diseases, metabolic syndrome and death (Ford and Caspersen 2012; Wilmot et al. 2012). Even when daily recommendations for physical activity (PA) are met, people can incur health risks if they spend an excessive amount of time in SB (O'Donoghue et al. 2016). Thus, knowing the factors that contribute to SB in populations can have important implications of public health.

SB can occur in four domains: household, occupational, transport and leisure time (Owen et al. 2011). Each domain can be affected by individual and environmental factors that are sociocultural, political, informational or natural (Owen et al. 2011). Environmental and individual factors act mutually and can have a higher or lower influence on a given health outcome (Diez Roux and Mair 2010; O'Donoghue et al. 2016). Although few studies have addressed the relationship between environmental factors and SB (Rhodes et al. 2012), different sets of factors might be associated with each SB domain (Koohsari et al. 2015;

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Owen et al. 2011), and this association might vary according to the profile of the evaluated population (Rhodes et al. 2012).

Although clear delimitation of a person's environment is rather difficult, the neighbourhood, *i.e.* the area near the home, is commonly used to investigate the environment's relationship to health outcomes (Diez Roux 2007). Sedentary activities in the leisure-time and transport domains are more prone to be influenced by neighbourhood characteristics (Owen et al. 2011). For example, the neighbourhood can directly promote SB by means of facilities or activities that encourage "sitting down", such as establishments that broadcast sports events or offer computer games. SB can also be influenced by substitution with PA (Barnett et al. 2015; Koohsari et al. 2014). This situation occurs in neighbourhoods with characteristics that favour walking (walkability), thus reducing motorized transport (Barnett et al. 2015; Koohsari et al. 2014; Owen et al. 2011), and that offer a broad range of facilities for PA, thus decreasing the time spent in sedentary leisure-time activities, such as TV viewing and using the computer (Owen et al. 2011; Storgaard et al. 2013).

Few studies of SB have analysed the neighbourhood using objective methods, *i.e.* by assessing its characteristics on site via observation, such as by auditing, or through the use of a geographic information system (GIS). In the audit procedure, researchers go through the environment assessing particular aspects of interest, whereas with the use of GIS, measurements are derived from data sources that have some spatial reference, such as addresses, and analysed using computer systems (Browson et al. 2009). Most SB studies have assessed the walkability and the socioeconomic status of neighbourhoods, and they generally found an inverse relationship of the former to SB and reported controversial results for the latter (Coogan et al. 2012; Ding et al. 2012; Frank et al. 2004; Koohsari et al. 2014; Kozo et al. 2012; Sugiyama et al. 2007; Van Dyck et al. 2010). Only one Danish study assessed another neighbourhood feature and found an inverse association between green space and SB in leisure (Storgaard et al. 2013). In relation to total SB or one of the SB domains, no other neighbourhood characteristics have been explored, including community associations, terrain slope and the presence of facilities that make it possible for residents to engage in leisure-time physical activity. Furthermore, only one study analysed the environment and SB in Brazil, and it only evaluated the perceived environment of participants (Goncalves et al. 2017). There are no studies of low–middle-income countries in which an audit was used to assess neighbourhood facilities, including retail establishments and gyms. Audits can reduce errors compared to the use of secondary data (Makelarski et al. 2013). Brazil has undergone a process of rapid urbanization that has caused problems with infrastructure and has resulted in social inequality (Santos 2013). These factors can create contrasts in city and neighbourhood characteristics and produce differences in the distribution of SB in the female population. Thus, the objective of the present survey was to assess the association between neighbourhood environmental variables and time spent in SB in the domains of leisure time and transport amongst women living in urban areas of a municipality in Southern Brazil.

Methods

Population and procedures

The present work is a cross-sectional study that is part of a larger survey entitled "Living conditions and health of adult women: population-based survey in Vale dos Sinos. Evaluation after 10 years", which was conducted in 2015.

The study population consisted of women between 20 and 69 years of age who lived in the urban area of São Leopoldo. Pregnant women, women lacking the physical or mental ability to answer the questionnaire or women who were unable to move, even partially, the week prior to the interview were excluded from the study. The sample size was determined according to the outcome that required the highest number of participants (delayed cytopathological examination). It was calculated considering an odds ratio of 2.0, a confidence level of 95%, a statistical power of 80% and a non-exposed/exposed ratio of 1:2. The calculated sample size was increased by 10% to compensate for losses and refusals and by 15% to control for confounding factors; thus, the sample totalled 1281 women. A two-stage cluster sampling design was adopted: in the first stage, 45 census tracts were chosen by systematic random sampling; in the second stage, 36 homes were selected from each tract. Of the eligible participants, 1126 women agreed to participate in the study (11.9% losses and refusals). Data were collected throughout an eight-month period. During home visits, the women completed a standardized, pre-codified and pre-tested questionnaire via interview, and the geographic coordinates of each house were recorded using a GPS (geographic position system) (eTrex Legend HCx; Garmin International, Inc., Olathe, Kansas). All interviewers were trained and had participated in a pilot study that was conducted in a non-selected census tract. Reliability was assessed by re-administering the questionnaire to a random sample of 10% of the participants and was not subject to short-term changes. The data were entered twice in EpiData 3.1 software and checked for typographical errors.

Dependent variables

The dependent variables of the study were excessive transport-related and leisure-time SB (ETSB and ELSB, respectively). SB was assessed using an instrument that was specifically developed for this survey (Electronic Supplementary Material). The instrument addressed the time spent per week sitting/lying in several situations on any day of the week and weekend prior to the interview. Activities performed in the domains leisure time (recreational computer, tablet or cell phone use at home; TV viewing; visiting/meeting friends; drinking tea; reading; religious activities; and crafts) and transport (motorized transport: car, motorcycle, train, bus) were assessed. If two activities were performed simultaneously, the interviewees were asked to choose the one they considered more important. SB in each domain was expressed in minutes per day. SB was calculated by adding the time spent in SB during all days of the week and dividing the result by seven. Since the outcomes did not exhibit a normal distribution and because there is a the lack of consistency regarding a time threshold for SB to be considered a health risk, a cut-off point was adopted based on the median that classifies outcomes in ETSB ($\geq$ 17 min/day) and ELSB ($\geq$ 163 min/day). This method has been used in other studies (Mielke et al. 2014; Storgaard et al. 2013). The reliability of the SB-measuring instrument was assessed by test–retest of 97 of the participants. For this analysis, SB values were transformed into dichotomous variables using the median as the cut-off point. Kappa values remained between 0.5 and 0.8, indicating moderate to substantial agreement.

Individual variables

The individual variables were divided into demographic variables [age (categorized in 10-year ranges), skin colour (white, non-white), marital status (with partner, without partner)]; socioeconomic variables [(socioeconomic status according to the Brazilian Market Research Association (Associação Brasileira de Empresas de Pesquisa 2014) A/B—richest, C, D/E—poorest, level of education (0 to 4, 5 to 7, 8 to 10, 11 to 14, $\geq$ 15 years), household income per capita (number of minimum wages in quartiles), employment (yes, no)]; and behavioural variables [smoking (non-smoker, smoker), alcohol consumption (< 30 g/day, $\geq$ 30 g/day) (Moreira et al. 1996), leisure-time physical activity ($\geq$ 150 min/week, < 150 min/week), measured using a modified version of the International Physical Activity Questionnaire (IPAQ) (Craig et al. 2003) and transport-related physical activity (yes, no)]. Other investigated variables included automobiles per household (none, one, two or more), computers per household (none, one, two or more), children per household (two or more, one, none) and self-perceived health (excellent/very good/good, fair/poor).

Neighbourhood environmental variables

The neighbourhoods were outlined by drawing a 400-m Euclidian buffer around the median point of the participants' homes in each sector. These procedures were calculated using ArcGIS software (ESRI®), version 10.3. Because some census tracts are very extensive, 28 women lived outside the buffers and were excluded from the study. One neighbourhood was also excluded because it encompassed a large area of the neighbouring municipality, thus implying the absence of street network data for this municipality. A total of 44 neighbourhoods and 1079 women remained in the study.

The neighbourhood environmental variables consisted of a set of characteristics that were divided into three groups: the built environment, the natural environment and the social environment. Variables were chosen to represent characteristics that directly or indirectly promote active leisure (any physical leisure-time activity) and/or transport by walking or biking. Thus, this study hypothesized that neighbourhoods with unfavourable environments for physical leisure-time activity and/or transport by walking or biking will contribute to a higher ratio of leisure-time and transport-related SB (Owen et al. 2011; Sugiyama et al. 2007). A 400-m buffer was used since it is a reasonable distance for an individual to walk to a point of interest (Brownson et al. 2009). A description of the analysed variables for each outcome, their definitions and the means of data acquisition is provided in Table 1.

Neighbourhood environmental variables were obtained by audit and from government data. The audit procedure was conducted over a period of 5 months and was performed by properly trained auditors, and each pair of auditors assessed approximately seven to eight neighbourhoods. Each pair of auditors was equipped with a map of the neighbourhood and covered all roads to record the geographic coordinates of each visualized facility and its respective description (retail establishment, gym, church, etc.) in the GPS. The facilities were then classified into categories for comparison of the variables assessed in the study. Neighbourhood environmental variables were analysed using GIS with ArcGIS software (ESRI®), version 10.3, and categorized into tertiles except in the case of "number of places to perform exercise per resident (PPEX/resident)", which exhibited medians of zero and was expressed as a dichotomous variable. For most of the neighbourhood environmental variables, the third tertile represented the category of the non-exposed; exceptions were the variables "terrain slope" and "distance to bicycle path", in which the exposed were those in the first tertile. Audit reliability was assessed by a test–retest in 20% of the neighbourhoods (two-week to two-month intervals).

Table 1 Description and definition of neighbourhood variables, source of data acquisition and corresponding outcomes. Brazil 2018

Neighbourhood variables	Definition	Source	Outcome
Built environment			
Number of residents (A)	Mean number of residents of the census tracts whose centroids comprise the buffer	IBGE	1 and 2
Number of retail establishments (B)	Number of retail establishments within the buffer	Audit	1 and 2
Number of intersections (C)	Number of intersections with at least three road segments within the buffer	City Hall street vector files	1 and 2
Total public recreation areas(PRA)/resident	Sum of areas of parks, squares and open-air public recreation spaces within the buffer/resident	Audit/IBGE	2
Number of places to perform exercise (PPEX)/resident	Number of gyms, sports schools and health centres that offer PA within the buffer/resident	Audit/IBGE	2
Number of associations and churches/resident	Number of associations and churches within the buffer/ resident	Audit/IBGE	2
Number of other places/ resident	Number of schools, entertainment centres, government organisations, public and private health establishments within the buffer/resident	Audit/IBGE	1
Distance to bicycle path (m)	Distance in a straight line from the centre point of the buffer to the nearest bicycle path	City Hall	1 and 2
Homes with street lighting (%)	Mean percentage of homes with street lighting in the census tracts of which the centroids comprise the buffer	IBGE	1 and 2
Walkability index[a]	Composed of variables A, B and C	Audit/IBGE	1 and 2
Natural environment			
Terrain slope (%)	Mean value of slopes (measurement of how steep the ground surface is) within the buffer	Contour lines City Hall	1 and 2
Social environment			
Income per capita (R$)	Mean income per capita in the census tracts of which the centroids comprise the buffer	IBGE	1 and 2

IBGE Brazilian Institute of Geography and Statistics (Instituto Brasileiro de Geografia e Estatística) (IBGE, 2010), *PA* physical activity, *1* excessive transport-related sedentary behaviour, *2* excessive leisure-time sedentary behaviour

[a]Walkability index: each variable (A, B, C) was divided into deciles and assigned a score (first decile = 1 to tenth decile = 10). The sum of the scores of all three variables comprised the walkability index of each neighbourhood (Sugyiama et al. 2007)

Weighted kappa values were obtained from the classification of variables into tertiles and ranged from 0.4 (other places) to 0.9 (retail establishments), with the observed variables reaching moderate to substantial agreement.

Statistical analysis

A distribution of the neighbourhood variables according to measures of central tendency and dispersion is shown. The variation of outcomes according to the analysed variables is expressed as odds ratios and 95% confidence intervals (95% CIs). Analyses were performed using Stata software, version 11.0 (Stata Corp., College Station, TX, USA).

The association of neighbourhood variables with ETSB and ELSB was assessed by multilevel logistic regression using MLwiN software (Centre for Multilevel Modelling, Bristol, UK), version 3.0, with the second-order predictive quasi-likelihood (PQL) method (Rasbash et al. 2000). A multilevel analysis was used to simultaneously assess the effect of group variables (neighbourhood, level II, distal) and individual variables (level I, proximal) on the outcome (Diez Roux 2002). In the present survey, neighbourhood variables were considered exposure variables, whereas individual variables were considered confounding variables. Only neighbourhood and individual variables that presented $p \leq 0.05$ in the bivariate analysis were considered for multivariate analysis. To avoid collinearity amongst variables that measured the same construct, only those with higher significance were used in the analysis. Thus, three analysis models were established: in Model 1, neighbourhood variables were adjusted for one another; in Model 2, each neighbourhood variable was adjusted for individual variables; and in Model 3, neighbourhood variables were adjusted for one another and for individual variables. All three models were used for each outcome (ETSB and ELSB). Associations were considered significant when the probability level was less than or equal to 5% ($p \leq 0.05$).

Results

The sample consisted of women with a mean age of 43.3 years (SD: 13.3), who were predominantly white skin colour (74.1%), who lived with a partner (63.9%) and who were employed (55.9%). The mean income per capita was 1.3 minimum wages (SD: 1.4), and the mean level of education was 9.8 years (SD 10.4). The women spent a mean of 202.9 (SD: 162.6) and 33.2 (SD: 56.0) minutes/day on SB in the transport and leisure-time domains, respectively (data not given in tables).

The 44 assessed neighbourhoods exhibited a mean of 571.2 (SD: 152.4) residents, 121.8 (SD: 155.7) retail establishments and 52.7 (SD: 14.9) road intersections. These indicators produced a mean walkability index of 17.1 (SD: 5.1). Approximately one-third of the neighbourhoods had only 0.8 m^2 total public recreation area (PRA)/resident, were located $\geq$ 2438 m from a bicycle path and had $\geq$ 6.2% terrain slope, and half of the sample had less than 0.0020 PPEX/resident. The mean neighbourhood per capita income was R$ 919.09 (SD: 533), and the mean percentage of homes with neighbourhood street lighting was 95.9% (5.9). The mean number of churches and associations per neighbourhood was 6.2 (SD: 5.7) (Table 2).

In the bivariate analysis of individual variables, younger women of the A/B class, with higher levels of education, higher income, two or more automobiles per household and who performed some type of physical activity during transport exhibited higher odds of ETSB. Conversely, unemployed women who smoked, were inactive during their leisure time and had fair/poor self-perceived health had lower chances of ETSB. For the domain leisure, class A/B unemployed women with one or more computers per household, not living with a child, who smoked and had fair/poor self-perceived health exhibited higher chances of ELSB, whereas women within the age range of 40 to 49 years exhibited lower chances of ELSB (Table 3).

In the bivariate analysis of neighbourhood environmental variables, women living in neighbourhoods with higher terrain slopes and low walkability index had higher odds of ETSB. Women living in neighbourhoods further from a bicycle path, with worse street lighting and with lower income had lower odds of ETSB. In the leisure domain, women living in neighbourhoods with lower PRA/resident had higher odds of ELSB. Finally, neighbourhoods that were classified as low PPEX/resident or had higher terrain slope and lower income exhibited reduced odds of ELSB amongst women (Tables 4, 5).

In the multivariate analysis for ETSB (Table 6), Model 1 showed that only income and terrain slope remained associated with the outcome. Higher-income neighbourhoods were associated with less ETSB, while neighbourhoods with higher slope were associated with more ETSB. After adjusting each neighbourhood environmental variable to the individual variables (Model 2), low walkability and high terrain slope were associated with more ETSB. Finally, in Model 3, only terrain slope remained associated with the outcome. For ELSB, Model 1 showed that women living in low-income and PPEX/resident neighbourhoods tended to have less ELSB, while those living in neighbourhoods with more PRA/resident tended to have more ELSB. In Model 2, the same variables remained associated with ELSB as in Model 1, whereas women living in

Table 2 Description of environmental variables analysed in the neighbourhoods (*n* = 44). Brazil 2018

Variables	Mean	SD	Median	Minimum	Maximum
Number of residents[a]	571.2	152.4	554.0	331.0	1103.0
Number of retail establishments[a]	121.8	155.7	68.0	13.0	855.0
Number of intersections[a]	52.7	14.9	52.5	18.0	89.0
Total public recreation area (m^2)/resident	6.9	9.2	4.0	0	43.0
Number of places to perform exercise/resident	0	0	0	0	0.03
Number of associations and churches/resident	0.01	0.01	0.01	0	0.4
Number of other places/resident	0.2	0.7	0.0	0	0.4
Distance to bicycle path (m)	2470.9	2718.7	1494.5	0	15,588.0
Homes with street lighting (%)	95.9	5.9	98.0	71.9	100.0
Walkability index[b]	17.1	5.1	17.5	6.0	28.0
Terrain slope (%)	4.6	3.7	3.8	0.3	11.8
Income per capita (R$)	919.9	533.0	701.0	380.4	2436.4

SD standard deviation

[a]Variables used to calculate the walkability index

[b]Walkability index: each variable (A, B, C) was divided into deciles and assigned a score (first decile = 1 to tenth decile = 10). The sum of the scores of all three variables comprised the walkability index of each neighbourhood (Sugyiama et al. 2007)

Table 3 Prevalence (%) and odds ratios with respective 95% confidence intervals, for excessive transport-related and leisure-time sedentary behaviour according to individual variables in adult women (n = 1079). Brazil 2018

Individual variables	% ETSB (95% CI)	OR (95% CI)	% ELSB (95% CI)	OR (95% CI)
Age range (years)				
60–69	37.1 (29.2–45.0)	1	62.2 (52.9–71.6)	1
50–59	38.1 (30.7–45.5)	1.1 (0.7–1.7)	52.1 (44.5–59.5)	0.7 (0.4–1.0)
40–49	52.7 (46.1–59.2)	**2.1 (1.4–3.2)**	40.1 (33.1–47.1)	**0.4 (0.3–0.6)**
30–39	53.8 (46.6–60.9)	**2.1 (1.4–3.2)**	44.5 (37.2–51.8)	**0.5 (0.3–0.8)**
20–29	57.1 (50.6–63.5)	**2.4 (1.5–3.7)**	59.5 (52.6–66.4)	0.9 (0.6–1.4)
Skin colour				
Not white	43.0 (36.5–49.5)	1	49.1 (43.5–54.7)	1
White	50.5 (45.1–55.8)	**1.4 (1.0–1.8)**	50.8 (46.6–54.9)	1.1 (0.8–1.4)
Marital status				
No partner	NA	–	51.0 (45.9–56.2)	1
Partner			49.9 (44.8–55.1)	1.0 (0.8–1.3)
Economic class[a]				
D and E	26.1 (19.0–33.2)	1	43.3 (37.1–49.5)	1
C	43.7 (39.3–48.0)	**2.2 (1.4–3.4)**	51.1 (45.2–56.9)	**1.4 (1.0–2.1)**
A and B	64.6 (57.3–71.9)	**5.3 (3.4–8.5)**	52.2 (46.4–57.9)	**1.5 (1.0–2.1)**
Level of education (years)				
0–4	25.2 (19.3–31.2)	1	49.5 (42.6–56.3)	1
5–7	38.8 (32.7–44.9)	**1.9 (1.3–2.9)**	47.9 (41.9–53.9)	0.9 (0.6–1.4)
8–10	40.5 (31.7–49.3)	**2.1 (1.3–3.2)**	50.0 (41.5–58.5)	1.0 (0.7–1.5)
11–14	64.0 (58.2–69.7)	**5.3 (3.6–7.9)**	51.3 (45.4–57.1)	1.1 (0.8–1.6)
15 or more	78.1 (69.7–86.5)	**10.7 (6.0–19.0)**	55.2 (46.2–64.3)	1.2 (0.8–2.0)
Income in MW[b]				
≤ 0.52	32.2 (27.3–37.1)	1	47.3 (41.0–53.6)	1
0.53–0.86	43.6 (37.7–49.5)	**1.6 (1.1–2.3)**	48.2 (41.5–55.0)	1.1 (0.8–1.5)
0.87–1.53	52.2 (44.4–60.0)	**2.3 (1.6–3.3)**	52.3 (44.6–59.9)	1.2 (0.9–1.7)
≥ 1.54	68.1 (60.4–75.7)	**4.5 (3.1–6.5)**	53.3 (46.2–60.4)	1.2 (0.9–1.8)
Employed				
Yes	60.7 (55.7–65.6)	1	41.0 (35.8–45.4)	1
No	33.3 (28.6–37.9)	**0.3 (0.3–0.4)**	62.5 (57.4–67.7)	**2.5 (1.9–3.2)**
Computers per household				
None	NA	**–**	47.3 (42.8–51.9)	1
One			50.9 (45.5–56.3)	1.2 (0.9–1.5)
Two or more			54.6 (46.8–62.5)	**1.3 (1.0–1.9)**
Children per household[c]				
Two or more	43.7 (32.4–55.0)	1	42.2 (30.8–53.6)	1
One	51.8 (46.6–57.0)	1.4 (0.9–2.1)	40.4 (34.0–46.7)	0.9 (0.6–1.4)
None	48.0 (42.8–53.2)	1.1 (0.8–1.7)	56.8 (52.4–61.3)	**1.9 (1.3–2.7)**
Automobiles per household				
None	34.2 (29.4–38.9)	1	50.5 (45.8–55.2)	1
One	53.1 (48.1–58.0)	**2.2 (1.7–2.9)**	50.4 (44.9–55.9)	1.0 (0.8–1.3)
Two or more	71.2 (60.7–81.8)	**4.8 (3.2–7.3)**	49.7 (39.7–59.7)	1.0 (0.7–1.4)
Smoking				
Non-smoker	50.3 (45.5–55.2)	1	48.9 (44.8–52.9)	1
Smoker	40.7 (34.6–46.8)	**0.7 (0.5–1.0)**	56.8 (50.9–62.6)	**1.4 (1.0–1.9)**
Alcohol (g/day)				
< 30	48.7 (44.3–53.0)	1	50.2 (46.4–54.0)	1
≥ 30	44.4 (25.6–63.3)	0.8 (0.4–1.8)	55.6 (37.0–74.1)	1.2 (0.6–2.6)

Table 3 (continued)

Individual variables	% ETSB (95% CI)	OR (95% CI)	% ELSB (95% CI)	OR (95% CI)
Transport-related PA				
Yes	45.2 (41.2–49.2)	1	49.7 (45.1–54.2)	1
No	55.2 (47.5–62.9)	**1.5 (1.1–1.9)**	51.7 (46.4–56.9)	1.1 (0.9–1.4)
Leisure-time PA (min/wk)				
$\geq$ 150	58.6 (49.4–67.7)	**1**	50.7 (41.2–60.1)	1
< 150	46.9 (42.7–51.2)	**0.7 (0.5–0.9)**	50.3 (46.3–54.2)	1.0 (0.7–1.4)
Self-perceived health				
Excellent/very good/good	54.6 (49.1–60.3)	1	48.3 (44.0–52.6)	1
Fair/poor	36.6 (32.6–40.6)	**0.5 (0.4–0.6)**	54.3 (49.5–59.0)	**1.3 (1.0–1.6)**

ETSB excessive transport-related sedentary behaviour, *ELSB* excessive leisure-time sedentary behaviour, *PA* physical activity, min/wk (minutes per week), *OR* odds ratio, *NA* variables not analysed because they were not part of the theoretical model related to the outcome

Values shown in bold are $p \leq 0.05$

[a]Socioeconomic status according to the Brazilian Market Research Association (A/B: richest; D/E: poorest) (Associação Brasileira de Empresas de Pesquisa (2014)

[b]*MW* minimum wage (value of minimum wage in 2015 = R$ 1006.88)

[c]$\leq$ 12 years

neighbourhoods with high terrain slope tended to have more ELSB. When neighbourhood environmental variables were adjusted to one another and to individual variables (Model 3), only the variable PRA/resident remained associated with ELSB.

Compared to the empty model, the contextual-level variances were reduced by 45% for ETSB and by 55% for ELSB after the joint inclusion of the neighbourhood variables. This result indicates that, for these outcomes, a large proportion of the areas' variance originated from differences in the contextual variables between the areas. With the inclusion of the individual variables, there was a greater reduction in variance for the ETSB outcome (83%) (Table 6).

Discussion

This study shows that some objectively measured neighbourhood environmental characteristics were associated with SB in the studied population. Women who lived in neighbourhoods with a higher percentage of terrain slope had 50% higher odds of exhibiting ETSB. Similarly, in the leisure domain, a lower PRA/resident ratio in the neighbourhood increased the odds of ELSB in women by 40%.

The association between terrain slope and ETSB was as expected and confirmed the hypothesis that difficulties in transport by walking or biking due to the environment can favour ETSB due to the increased use of motorized transport. No published studies have evaluated the relationship between terrain slope and SB. However, some studies have found that terrains with higher slopes are directly associated with less PA during commuting (Kang et al. 2017; Lee and Moudon 2006).

In the model that analysed each neighbourhood variable fitted to individual variables, lower walkability indices increased the odds of ETSB in women by 40%. However, when the remaining neighbourhood variables were included, this result lost statistical significance. In studies conducted in the USA, individuals whose living areas offered more walkability tended to use their automobiles less often (Frank et al. 2004; Kozo et al. 2012). Although the direction of the association found in the above-cited studies is similar to that observed in the present work, comparisons should be made with caution given that both the SB domains and the methods used to evaluate walkability differed. Whereas our study used all SB performed during transport to constitute the domain, *i.e.* time spent in an automobile, on a bus or on a motorcycle, the cited studies only used the time spent in an automobile. Although the components of walkability used in the studies are similar, the index was calculated differently, and the size of the evaluated area also varied.

The present work shows that PRA/resident was inversely associated with ELSB amongst women, consistent with the results of surveys conducted in Europe (Compernolle et al. 2016; Storgaard et al. 2013). The presence of PRA might have encouraged the women to perform open-air PA at the expense of sedentary activity in closed environments. Although the present survey did not

Table 4 Prevalence (%) and odds ratios with the respective 95% confidence intervals of excessive transport-related sedentary behaviour according to neighbourhood variables in adult women (n = 1079). Brazil 2018

Neighbourhood variables	% ETSB (95% CI)	OR (95% CI)
Number of other places/resident		
High (≥ 0.0046)	48.6 (43.1–54.1)	1
Medium (≥ 0.0015 ≤ 0.0045)	49.4 (40.6–58.3)	1.1 (0.7–1.7)
Low (≤ 0.0014)	47.7 (39.9–55.5)	1.0 (0.6–1.5)
Distance to bicycle path (m)		
Low (≤ 1128)	56.5 (48.1–64.9)	1
Medium (≥ 1129 ≤ 2437)	48.8 (41.8–55.7)	0.8 (0.5–1.1)
High (≥ 2438)	**41.3 (36.4–46.4)**	**0.6 (0.4–0.8)**
Homes with street lighting (%)		
High (≥ 98.9)	53.6 (43.2–63.9)	1
Medium (≥ 96.6 ≤ 98.8)	48.8 (42.2–55.4)	0.8 (0.6–1.3)
Low (≤ 96.5)	**44.6 (39.0–50.3)**	**0.6 (0.4–1.0)**
Walkability index[a]		
High (≥ 19)	45.7 (40.8–50.7)	1
Medium (≥ 15 ≤ 18)	47.8 (39.8–55.8)	1.1 (0.7–1.7)
Low (≤ 14)	**54.2 (43.8–64.6)**	**1.4 (1.0–2.1)**
Terrain slope (%)		
Low (≤ 1.41)	44.8 (38.9–50.7)	1
Medium (≥ 1.42 ≤ 6.20)	47.3 (39.2–55.4)	1.1 (0.8–1.7)
High (≥ 6.21)	**53.3 (46.0–60.7)**	**1.5 (1.0–2.3)**
Income (R$)		
High (≥ 895.7)	61.5 (52.4–70.8)	1
Medium (≥ 620.6 ≤ 895.6)	**45.7 (40.1–51.3)**	**0.5 (0.4–0.8)**
Low (≤ 620.5)	**43.1 (38.0–48.2)**	**0.5 (0.3–0.7)**

ETSB excessive transport-related sedentary behaviour, *CI* confidence interval, *OR* odds ratio

Values shown in bold are $p \leq 0.05$

[a]Walkability index: each variable (A, B, C) was divided into deciles and assigned a score (first decile = 1 until tenth decile = 10). The sum of the scores for all three variables comprised the walkability index of the neighbourhood (Sugyiama et al. 2007)

Table 5 Prevalence (%) and odds ratios with respective 95% confidence intervals for excessive leisure-time sedentary behaviour according to neighbourhood variables in adult women (n = 1079). Brazil 2018

Neighbourhood variables	% ELSB (95% CI)	OR (95% CI)
Total public recreation area (m^2)/resident		
High (≥ 8.8)	45.8 (38.2–53.4)	1
Medium (≥ 0.81 ≤ 8.7)	51.3 (47.0–55.5)	1.2 (0.8–1.7)
Low (≤ 0.80)	53.8 (47.7–60.0)	**1.4 (1.0–2.0)**
Number of places to perform exercise/resident		
High (≥ 0.0021)	56.8 (49.9–63.6)	**1**
Low (< 0.0020)	46.6 (42.8–50.5)	**0.7 (0.5–0.9)**
Number of associations and churches/resident		
High (≥ 0.0148)	48.1 (43.7–52.4)	1
Medium (≥ 0.005 ≤ 0.0147)	50.0 (42.3–57.7)	1.1 (0.8–1.6)
Low (≤ 0.004)	53.0 (46.0–59.9)	1.2 (0.9–1.8)
Distance to bicycle path (m)		
Low (≤ 1128)	48.0 (39.7–56.4)	1
Medium (≥ 1129 ≤ 2437)	52.3 (46.3–58.3)	1.1 (0.8–1.6)
High (≥ 2438)	50.4 (45.5–55.3)	1.1 (0.7–1.5)
Homes with street lighting (%)		
High (≥ 98.9)	54.3 (47.8–60.7)	1
Medium (≥ 96.6 ≤ 98.8)	49.1 (42.7–55.5)	0.8 (0.5–1.1)
Low (≤ 96.5)	48.6 (42.1–55.1)	0.8 (0.5–1.1)
Walkability index[a]		
High (≥ 19)	51.4 (47.1–55.8)	1
Medium (≥ 15 ≤ 18)	44.7 (36.8–52.5)	0.8 (0.5–1.1)
Low (≤ 14)	53.2 (44.6–61.8)	1.1 (0.8–1.5)
Terrain slope (%)		
Low (≤ 1.41)	53.7 (48.8–58.5)	1
Medium (≥ 1.42 ≤ 6.20)	53.5 (46.9–60.0)	1.0 (0.7–1.5)
High (≥ 6.21)	**43.9 (37.6–50.3)**	**0.7 (0.5–1.0)**
Income (R$)		
High (≥ 895.7)	57.4 (51.5–64.8)	1
Medium (≥ 620.6 ≤ 895.6)	50.7 (43.6–57.8)	0.8 (0.5–1.1)
Low (≤ 620.5)	45.8 (41.3–50.2)	**0.6 (0.4–0.9)**

ELSB excessive leisure-time sedentary behaviour, *CI* confidence interval, *OR* odds ratio

Values shown in bold are $p \leq 0.05$

[a]Walkability index: each variable (A, B, C) was divided into deciles and assigned a score (first decile = 1 to tenth decile = 10). The sum of the scores for all three variables comprised the walkability index of the neighbourhood (Sugyiama et al. 2007)

specifically address natural spaces, such as green areas, many spaces included in this variable were composed of public squares, which usually have green areas. Thus, in addition to the area available for walking or performing other leisure-time activities, squares can also represent green areas. When these factors are absent, they can predict higher levels of SB (Triguero-Mas et al. 2015) and can negatively affect the overall and mental health of individuals (Teychenne et al. 2014).

Amongst the models used to explain ELSB, we also found neighbourhood variables that exhibited significance in Model 2, but not in the final analysis, as occurred for PPEX/resident, income and terrain slope. The presence of other neighbourhood variables might have nullified the effects of these variables. An effect was found in an unexpected direction for PPEX/resident, indicating that the odds of ELSB were reduced by 30% in women who lived in neighbourhoods with lower PPEX/resident. This finding might be explained by the fact that the number of PPEX/

Table 6 Multilevel logistic regression models of the effect of neighbourhood on excessive transport-related and leisure-time sedentary behaviour in adult women (n = 1079). Brazil 2018

Neighbourhood variables	Empty model	ETSB		
		Model 1 OR (95% CI)	Model 2[A] OR (95% CI)	Model 3 OR (95% CI)
Distance to bicycle path (m)				
Low (≤ 1128)		1.0	1.0	1.0
Medium (≥ 1129 ≤ 2437)		0.8 (0.5–1.3)	1.1 (0.7–1.6)	1.2 (0.8–1.8)
High (≥ 2438)		0.8 (0.5–1.3)	0.9 (0.7–1.2)	1.2 (0.8–2.0)
Homes with street lighting (%)				
High (≥ 98.9)		1.0	1.0	1.0
Medium (≥ 96.6 ≤ 98.8)		1.1 (0.7–1.6)	1.0 (0.7–1.5)	1.1 (0.7–1.7)
Low (≤ 96.5)		0.9 (0.6–1.4)	1.2 (0.8–1.8)	1.4 (0.9–2.1)
Walkability index				
High (≥ 19)		1.0	1.0	1.0
Medium (≥ 15 ≤ 18)		0.8 (0.5–1.3)	1.1 (0.7–1.5)	0.9 (0.6–1.3)
Low (≤ 14)		1.3 (0.8–1.9)	**1.4 (1.0–2.0)**	1.2 (0.8–1.7)
Terrain slope (%)				
Low (≤ 1.41)		1.0	1.0	1.0
Medium (≥ 1.42 ≤ 6.20)		1.0 (0.7–1.6)	1.2 (0.8–1.7)	1.2 (0.8–1.9)
High (≥ 6.21)		**1.5 (0.9–2.4)**	**1.5 (1.0–2.1)**	**1.5 (1.0–2.4)**
Income (R$)				
High (≥ 751.00)		1.0	1.0	1.0
Medium (≥ 620.49 ≤ 750.99)		**0.6 (0.4–1.0)**	0.8 (0.5–1.2)	0.7 (0.5–1.1)
Low (≤ 620.48)		**0.5 (0.3–0.9)**	1.0 (0.7–1.5)	0.8 (0.5–1.4)
Variance (SE)	0.185 (0.078)	0.102 (0.061)	–	0.032 (0.054)
Reduction of variance (%)		44.9		82.7

Neighbourhood variables	Empty model	ELSB		
		Model 1 OR (95% CI)	Model 2[B] OR (95% CI)	Model 3 OR (95% CI)
Number of places to perform exercise/resident				
High (≥ 0.0019/resident)		1.0	1.0	1.0
Low (< 0.0019/resident)		**0.7 (0.5–1.0)**	**0.7 (0.5–1.0)**	0.8 (0.6–1.1)
Total public recreation area/resident				
High (> 8.70 m^2/resident)		1.0	1.0	1.0
Medium (≥ 0.81 ≤ 8.70 m^2/resident)		1.2 (0.8–1.7)	1.2 (0.9–1.8)	1.2 (0.8–1.8)
Low (≤ 0.80 m^2/resident)		**1.4 (1.0–2.0)**	**1.5 (1.0–2.1)**	**1.4 (1.0–2.1)**
Income (R$)				
High (≥ 751.00)		1.0	1.0	1.0
Medium (≥ 620.49 ≤ 750.99)		**0.7 (0.5–1.0)**	0.8 (0.6–1.2)	0.8 (0.5–1.2)
Low (≤ 620.48)		**0.7 (0.5–1.0)**	**0.7 (0.4–1.0)**	0.7 (0.5–1.1)
Terrain slope (%)				
Low (≤ 1.41)		1.0	1.0	1.0
Medium (≥ 1.42 ≤ 6.20)		1.2 (0.8–1.6)	1.1 (0.7–1.5)	1.2 (0.8–1.7)
High (≥ 6.21)		0.8 (0.6–1.2)	**0.7 (0.5–1.0)**	0.8 (0.6–1.3)
Variance (SE)	0.105 (0.060)	0.047 (0.048)	–	0.066 (0.056)

Table 6 (continued)

Neighbourhood variables	Empty model	ELSB		
		Model 1 OR (95% CI)	Model 2[B] OR (95% CI)	Model 3 OR (95% CI)
Reduction in variance		55.2		37.1

ETSB excessive transport-related sedentary behaviour, *OR* odds ratio, *CI* confidence interval, *ELSB* excessive leisure-time sedentary behaviour, *SE* standard error

Values shown in bold are $p \leq 0.05$

In Model 1, neighbourhood variables were adjusted for one another; in Model 2, each neighbourhood variable was adjusted for individual variables ([A]age range, skin colour, economic class, level of education, income, employment, presence of an automobile in the household, smoking, physical leisure-time activity, physical transport-related activity and self-perceived health; [B]age range, economic class, employment, presence of a computer in the household, presence of a child in the household, smoking, self-perceived health); in Model 3, neighbourhood variables were adjusted for one another and to the individual variables in Model 2

resident alone was not sufficient to measure the access women had to such places; other characteristics such as price or quality should also be considered (Handy and Clifton 2001). Similarly, contrary to our expectation, living in neighbourhoods with a lower income was associated with lower ELSB. Income is a proxy for neighbourhood characteristics that were not measured directly (Diez Roux et al. 2001) and that are related to both the generally available infrastructure and the conservation of physical spaces. The hypothesis that poorer neighbourhoods exhibit worse physical conditions and infrastructure for open-air activity, thus favouring ELSB, was not confirmed in this survey. Interestingly, terrain slope exhibited an opposite effect on ELSB relative to its effect in the transport domain, showing that the environment can interfere differently in each SB domain, as reported in a study that assessed terrain slope and physical leisure-time and transport activity (Lee and Moudon 2006).

One of the limitations of the present work is its cross-sectional design, which does not allow us to establish a cause–effect relationship between neighbourhood characteristics and SB in women. Another limitation lies in the use of a subjective SB-measuring instrument that has not yet been validated against an objective measuring method. Hence, the possibility that SB in women was over- or underestimated cannot be excluded. However, it is important to note that in general the questionnaire exhibited good reproducibility. Furthermore, although some associations between neighbourhood environmental characteristics and SB in women were found, whether this was the result of the substitution of physical activity for sedentary behaviour remains an open question. Moreover, the places in which sedentary activities were performed by women could not be determined to confirm the hypothesis that this occurred within the neighbourhood buffer. To answer these questions, future studies must simultaneously assess the activities performed by women, both sedentary and not, and the places where these activities occur (Koohsari et al. 2015).

To our knowledge, this is the first study in which the association between the neighbourhood environment and SB in the domains leisure time and transport has been assessed in a representative female population in Brazil using objective measures of the environment. The use of this method allowed the study to better elucidate neighbourhood environmental characteristics and, more specifically, avoided a large time gap between SB manifestation and data on the environment, as occurs in the evaluation of numbers of retail establishments and gyms, for example. Furthermore, the association of some environmental characteristics such as terrain slope and PPEX with SB was assessed for the first time. The reduction in the variance found after inclusion of the individual and contextual variables to some extent indicates that the variables used in the final model were sufficient for the evaluation of the contextual effects.

Conclusion

The present work shows that living in a neighbourhood with higher terrain slope increased the odds of women exhibiting ETSB, whereas living in a neighbourhood with fewer public recreation areas per resident increased the odds of ELSB. Our hypothesis was partially confirmed by a conceptual model in which the residents of neighbourhoods with worse conditions for walking or biking are more prone to transport-related SB and the residents of neighbourhoods with fewer available facilities for performing leisure-time activities tended to engage in more leisure-time SB. The fact that many of the analysed variables exhibited no associations with SB could be due to an actual absence of relationships between these variables and SB or to the possibility that these characteristics did not present sufficient variability in the urban setting to permit the detection of such associations. Nevertheless, the findings indicate that improvements in urban planning can have a beneficial impact on women's health by reducing the odds of SB.

Compliance with ethical standards

Ethical approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Declaration of Helsinki and its later amendments or comparable ethical standards.

Informed consent Informed consent was obtained from all individual participants included in the study. The study was approved by the Research Ethics Committee of the Universidade do Vale do Rio dos Sinos (University of Vale do Rio dos Sinos) under number 653.394.

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