International Journal of Public Health
https://doi.org/10.1007/s00038-019-01225-0

ORIGINAL ARTICLE

The influence of built, natural and social environment on physical activity among adults and elderly in southern Brazil: a population-based study

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Received: 11 September 2018 / Revised: 13 February 2019 / Accepted: 19 February 2019

Abstract

Objectives This study investigated the association of built, natural and social environment variables with the practice of physical activity (PA) during leisure time and commuting.

Methods Household interviews were carried out with a representative sample of individuals aged 18 years or older from a municipality in southern Brazil. PA was measured by the International Physical Activity Questionnaire, and households were georeferenced with a 500-m buffer.

Results Few associations between environmental variables and PA practice were identified. Only proximity to the seafront, presence of private gyms or sports clubs and higher average monthly income of the household head were associated with the practice of PA. In addition, there were inconsistencies in the findings showing that the associations varied based on the intensity and modality of PA within the same domain.

Conclusions This study provides evidence on the lack of association between objective environmental measures and the practice of PA. Although there were few significant results and the presence of inconsistencies in the findings, some environmental variables were associated with a more frequent practice of PA.

Keywords Environment · Leisure activity · Geographic information system · Walking · Spatial analysis · Urban population

Introduction

The regular practice of physical activity (PA) is critical for the prevention of chronic non-communicable diseases (NCD) and reduced mortality (Lee et al. 2012). Epidemiological studies have indicated that PA is also associated with lower risks of obesity, hypertension, coronary heart disease, stroke, type 2 diabetes, metabolic syndrome, osteoporosis and some forms of cancers (Bauman et al. 2012; Garber et al. 2011). While the beneficial effects of PA are well documented in the scientific literature (Lee et al. 2012), approximately one-third (31%) of the worldwide population remains physically inactive (Hallal et al. 2012), particularly in wealthier and urban countries (Dumith et al. 2011). In Brazil, the national prevalence of physical inactivity is 46% (VIGITEL 2017).

Currently, there has been an expansion in the number and types of variables considered as PA determinants, which have included not only individual factors but also characteristics of the environment. One example is the "ecological model," which focuses on the influence of political and built environment factors and intrapersonal and social aspects on the practice of PA (Sallis et al. 2006). From a macro-standpoint, one should also consider the influence of the natural, sociocultural and information

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Published online: 28 February 2019

environment on such a behavior (Sallis et al. 2006). According to this model, the environment may generate opportunities or barriers for the creation of healthy habits (Sallis et al. 2006). These models have been recognized as being more comprehensive and promising for the study of PA at a population level, since environmental interventions can reach a larger fraction of the population when compared to interventions at the individual level (Hino et al. 2010).

Different environment dimensions can be identified, namely built, natural, social and perceived. The built environment comprises structures and spaces constructed or modified by mankind, which include street design and networks, sidewalks, bicycle lanes, green space, transportation system, public and private recreational facilities, among others (Hino et al. 2010). The natural environment is composed of ecosystem resources, such as climate, vegetation and topography (Hino et al. 2010). The social environment includes elements related to individual living conditions such as income, schooling, criminal records, as well as characteristics associated with greater or lesser social disorder and social deprivation in the neighborhood (Macintyre et al. 2002). Lastly, the perceived environment consists of the analysis on how the individuals perceive the characteristics surrounding their home (Hino et al. 2010).

Several tools to analyze environmental variables are available, which encompass multiple assessment approaches and can be considered first-generation measures (Brownson et al. 2009). Recent evidence suggests that the design of urban environments may contribute substantially to the practice of PA (Sallis et al. 2016). An example of that is the more frequent presence of active individuals in places with more public spaces and green areas for the practice of PA (Sugiyama et al. 2012). Nonetheless, the literature remains controversial with regard to the association between environmental variables and PA practice, in that none or only a few associations have been identified (Wendel-Vos et al. 2007). Some hypotheses for that relate the study design (mostly cross-sectional), self-reported PA, and low quality of some environmental measures.

A comprehensive review (Bauman et al. 2012) identified a few consistent correlates of the built environment for specific transport domains (e.g., walkability and street connectivity) and leisure PA (e.g., pavement and safety of crossings, greenness and rated attractiveness as well as proximity to recreation facilities and locations). A study carried out in eleven countries showed that the associations of some neighborhood characteristics with the practice of PA tend to differ by country (Ding et al. 2013). Thus, this study aimed to investigate the association of built, natural and social environment variables with the practice of PA during leisure time and commuting in adults and elderly from southern Brazil, a rapidly developing country.

Methods

Study design and ethical approval

This was a population-based cross-sectional study that was part of a larger research project entitled "Health of the Riograndina population." The objective of this project was to evaluate health aspects of the resident population in the urban area of the municipality of Rio Grande, Brazil. Individuals institutionalized in nursing homes, hospitals and prisons or those with physical and/or mental incapacity to answer the questionnaire were not eligible. This study was previously approved by the Research Ethics Committee at the Health Center (CEPAS) of the Federal University of Rio Grande (FURG), under Protocol No. 20/2016.

Study location

The municipality of Rio Grande is located in the extreme south of the country near the border with Uruguay. The area has a coastal plain and flat topography. According to the data from the last population census of the Brazilian Institute of Geography and Statistics (IBGE 2011), Rio Grande has approximately 200,000 inhabitants, with 96% of them residing in the urban area. The climate in the region is temperate, with strong oceanic influences and relatively cold winters, hot summers, and abundant precipitation throughout the year. The economy of Rio Grande is mostly based on port activity as it is one of the major gateways for exportation of grains and importation of containers and fertilizers in Brazil. The Port of Rio Grande is the one of the biggest maritime ports in the country, with imports from, and exports to, all continents. Moreover, Rio Grande has a seaside resort, known as "Casino Beach," and features the longest beach in the world in extension, with nearly 300 km.

Sample size

In this study, the sample calculation was performed considering a 10% expected prevalence of the four outcomes, an error of two percentage points, a 95% confidence interval, an approximate population of 150 thousand people and an effect of sampling design of 1.5, resulting in 1290 individuals. Another 10% of sample dropouts or refusals was considered, totaling 1420 individuals. To study the associated factors, the following parameters were used for sample calculation: 95% confidence level; 80% statistical power; 10% prevalence of outcome; 20% to 60% frequency of exposure; and a prevalence ratio of at least 2.0, totaling 784 individuals. Another 50% were added for the

effect of the sample design and an additional 15% for possible confounding factors, resulting in 1294 individuals. In addition, an additional 10% was considered for possible dropouts and refusals, totaling a final sample of 1423 individuals.

The sampling process was based on data from the 2010 Demographic Census (IBGE 2011), from which it was possible to identify that the average number of residents aged 18 years or older *per* household was two individuals. Therefore, to obtain an approximate *N* of 1420 individuals, a total of 710 households should be considered. The sampling process occurred in two phases: the first phase being the selection of census sectors, and then the selection of households. To reduce the sampling design effect, an average of ten households *per* sector was used, hence requiring the analysis of 71 census sectors. Further details regarding the sampling process, field work and research instrument are published elsewhere (Dumith et al. 2018).

Logistic and procedures

The first phase of the present study comprised data collection through the cross-sectional research project entitled "Health of the Riograndina population." The field work consisted of household face-to-face interviews, from April to July 2016, performed by trained interviewers using a structured and previously tested questionnaire, with an average duration of 30 min. Those who accepted to participate in the study signed an informed consent form. The data collected were double-typed into EpiData 3.1 software. The geographic coordinates of the households were collected through Global Positioning System (GPS) during the application of the questionnaires. This led to the second phase of the study, carried out between January and November 2017, which consisted of georeferencing the households according to the streets network provided by the Federal Institute of Rio Grande (IFRS). During the same period, environmental variables were collected and geocoded using the ArcGIS 10.4 software.

Dependent variables

The outcome analyzed in this study was the practice of PA during leisure time and commuting. The data were collected using the long version of the International Physical Activity Questionnaire (IPAQ) validated for the Brazilian population (Craig et al. 2003; Matsudo et al. 2001). Study participants were inquired about activities performed up to 7 days prior to the interview, and only activities that lasted at least 10 consecutive minutes were considered. Leisure-time PA was analyzed separately according to intensity as walking and moderate to vigorous PA (MVPA). Commuting PA was analyzed as walking and cycling. The practice of any of these four outcomes, regardless of duration and weekly frequency, was considered.

Independent variables

The attributes of the environment were considered as independent variables. As shown in Table 1, these variables were extracted from four sources, namely IBGE, satellite image, Secretariat of Finance, and Military Police. For some variables, such as the presence of public and private places for the practice of PA, a 500-m circular buffer was used around the individuals' residences. The buffer size was defined considering the distance predicted to be reached by the individual when walking moderately for 10 min (Hino et al. 2010).

The insecurity variables (incidence of homicide, mugging, home burglary, commercial venue robbery, robbery on public transportation, and robbery or theft of vehicles) were grouped into a single variable through a main component analysis. With this, the first component was extracted, which explained 57% of the variability of the seven variables examined (*eigenvalue* = 4.01). The variables population density, average monthly income of the household head in the census sector, number of bus stops, proportion of public lighting, paved streets, sidewalks, trees, curbs, accessibility ramps, manhole/downtake pipes, absence of open sewage, absence of garbage accumulated in the streets and public insecurity were transformed into *Z* scores due to the lack of cutoff points to categorize them.

Intervening variables

The following variables were considered for adjustment purposes: gender (male/female), age (in full years), skin color (white/brown/black/other), marital status (single, married, divorced or widowed), assets index (*Z* score) and dwelling time in the neighborhood (how long the individuals had been living there, in years). The creation of the variable assets index considered 11 items, including characteristics of the home (e.g., number of bathrooms in the house) and household assets (such as a landline). The main component analysis extracted the first component, which explained 31% of the variability of all aspects examined (Filmer and Pritchett 2001).

Statistical analysis

The environmental variables were processed using ArcGIS 10.4 software and tabulated into a Microsoft Office Excel spreadsheet. The data were exported to *Stata 13.0* software for statistical analysis. Crude and adjusted analysis was performed by Poisson regression, taking into account the effect of sampling design. For the adjusted analysis, two

Table 1 Definition of environment variables in the city of Rio Grande, Brazil, 2017 (N = 1294)

Variables	Description	Source	Operationalization
Demographic density	Number of inhabitants/area of the sector in km^2 for each census tract	IBGE 2010 data + data obtained in ArcGIS	Z score
Average monthly income of the head of the family per sector	Average income of the head of the family by census tract	IBGE/2010 data	Z score
Presence of parks and squares	Presence of parks and public squares in each *buffer*	Satellite image/2017	No/Yes
Presence of hiking trails/ bike paths	Presence of hiking trails/cycle paths in each *buffer*	Satellite image/2017	No/Yes
Presence of cycle tracks	Presence of cycles in each *buffer*	Satellite image/2017	No/Yes
Presence of private gyms/ sports clubs	Presence of private gyms/sports clubs in each *buffer*	Data provided by the Rio Grande Finance Department	No/Yes
Presence of public gyms	Presence of public gyms in each *buffer*	Satellite image/2017	No/Yes
Number of bus stops	Presence of bus stops in each *buffer*	Satellite image/2017	Z score
Proximity to the seafront	Distance from home to the seafront	Satellite image/2017	$\leq$ 2 km/< 2 km away
Proportion of street lighting	Proportion of households with nearby street lighting	IBGE/2010 data	Z score
Proportion of paved streets	Proportion of households with nearby paved streets	IBGE/2010 data	Z score
Proportion of sidewalks	Proportion of households with nearby sidewalks	IBGE/2010 data	Z score
Curbs	Proportion of homes with nearby curbs	IBGE/2010 data	Z score
Presence of wheelchair ramp	Proportion of households with next wheelchair ramp	IBGE/2010 data	Z score
Manhole/downtake pipes	Proportion of households with manhole/downtake pipes	IBGE/2010 data	Z score
Proportion of afforestation	Proportion of households with presence of nearby trees	IBGE/2010 data	Z score
Proportion of nonexistent open sewage	Proportion of households without nearby open sewage	IBGE/2010 data	Z score
Proportion of non-accumulated garbage on the streets	Proportion of households without garbage accumulated in the streets	IBGE/2010 data	Z score
Insecurity	Record of the number of occurrences of each of these events (incidence of homicide, mugging, home burglary, commercial venue robbery, robbery on public transportation and theft of vehicles) by neighborhood	Military Police of the municipality/2017	Analysis of main components transformed into Z score

IBGE Brazilian Institute of Geography and Statistics

models were constructed as follows: In the first, only the intervening variables were included; in the second, the variables of the first model plus the other environmental variables were included. Only the analysis of the second model is presented herein. The data are expressed as prevalence ratio (PR) and 95% confidence interval (95% CI). The level of statistical significance was 5% for two-tailed tests.

Results

Of the 1429 individuals eligible for the study, 1300 (91%) from 676 households answered the questionnaire. There was a higher percentage of sample losses among males, with no differences according to age. As some individuals did not respond to all outcomes, the sample size (N) ranged from 1286 (walking for commuting) to 1294 (leisure-time walking).

The mean age of the sample was 46.1 years (SD 17.3), ranging from 18 to 96 years, with a median monthly income *per* capita of 1000 BRL (interquartile interval ranged from 600 to 1760 BRL), which corresponds to about one minimum wage in Brazil ($\sim$ US$ 250.00). Most individuals in the sample were females (57%), 83% were Caucasian, 46% were single, 42% had up to 8 years of schooling, and 36% had been living in the neighborhood for over 10 years. The averages of the environment variables transformed into Z scores were as follows—population density (inhab/km^2): 6340.2 (SD 5276.4); average

monthly household income in the census sector: 1411 BRL (SD 971); number of bus stops: 7.1 (SD 5.8).

As shown in Fig. 1, the prevalence of each outcome was 19% (95% CI 16–22) for leisure-time walking, 21% (95% CI 17–24) for cycling for commuting, 24% (95% CI 21–26) for MVPA and 58% (95% CI 54–62) for walking for commuting. Figure 2 shows the distribution of environmental variables in the sample, which varied from 2.6% for the proportion of households with open sewage and garbage accumulated in the streets to 63.0% for the presence of private gyms or sports clubs. Seven variables (out of 15, in total) had a coverage around 50% to 60%, whereas bicycle lanes, parks, squares and public gyms were present in < 40% of the household buffer.

Table 2 shows the crude and adjusted associations between the characteristics of the environment and leisure-time PA. The habit of walking was 19% (95% CI 4–36) higher for each *Z* score increase in the average monthly income of the household head and 40% higher (95% CI 2–93) in places with walking paths and bicycle lanes within the buffer. In addition, individuals who lived near the seafront had a 73% greater probability (95% CI 29–133) of walking in their free time. An increase in the *Z* score concerning the proportion of paving and insecurity indicated an increment of 17% (95% CI 0–36) and 32% (95% CI 10–58), respectively, in the probability of walking. The proportion of public lighting presented signs of association, with an increase in *Z* scores responsible for an increment of 22% (95% CI 0–49) in the probability of walking. Following the adjusted analysis, only the average monthly income of the household head in the census sector remained associated with the practice of leisure-time PA, in which an increase in the *Z* score augmented by 11% the probability of walking during leisure time (95% CI 2–21).

The practice of MVPA was 69% (95% CI 30–120) higher among individuals living near the seafront. An increase in each *Z* score of the household's average monthly income and insecurity incremented by 19% (95% CI 7–32) and 24% (95% CI 6–45), respectively, the probability of individuals practicing moderate to vigorous PA during their leisure time. An increase in each *Z* score of the population density decreased such a probability by 14% (95% CI 27–0). Following the adjusted analysis, no variable remained significantly associated with this outcome.

Table 3 shows the crude and adjusted associations between the environmental characteristics and the practice of PA during commuting. Living in places with parks and squares (19%, 95% CI 6–34) and the presence of private gyms and sports clubs (18%, 95% CI 4–35) within the buffer increased the probability of walking for commuting. An increase in the *Z* score of both variables "proportion of absence of open sewage" and "proportion of absence of garbage accumulated in the streets" increased by 7% the probability of individuals walking for commuting (95% CI 1–14 and 1–13, respectively). After adjusting for possible confounding factors, the presence of parks and squares in the buffer, the proportion of absence of open sewage and the absence of garbage accumulated in the streets no longer showed an association with the practice of PA during commuting. There was a significant association with the presence of curbs, in which an increase in the *Z* score decreased by 17% (95% CI 17–5) the probability of individuals walking for commuting. On the other hand, the presence of private gyms and sports clubs remained associated with a 23% (95% CI 8–41) greater probability of actively walking for commuting.

Cycling for commuting occurred less frequently (23%, 95% CI 3–54) among individuals who lived in places with squares and parks within the buffer. An increase in the

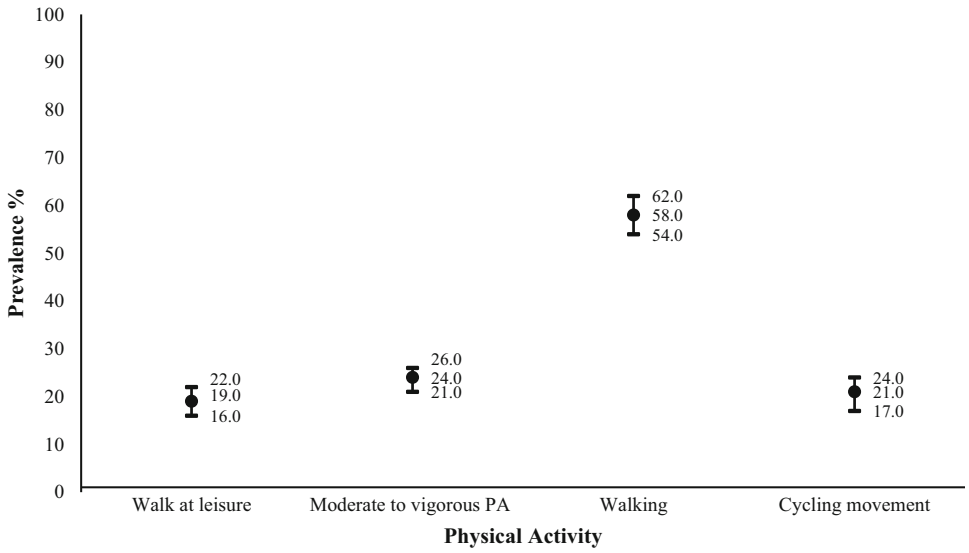
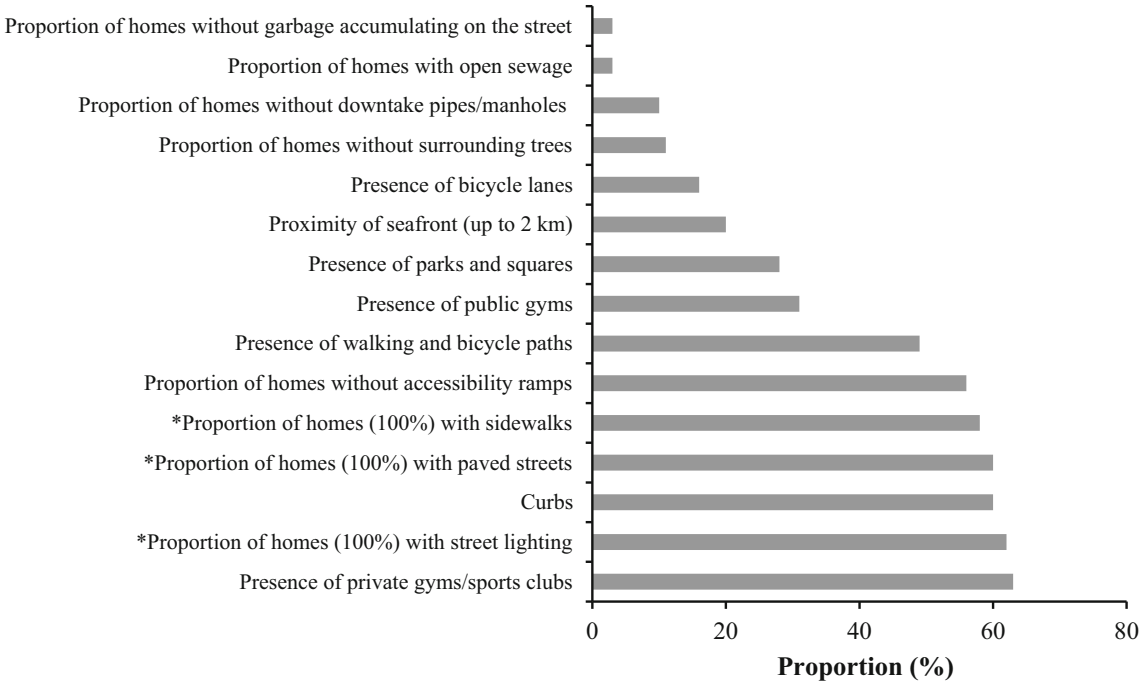


Fig. 1 Prevalence and 95% confidence interval (95% CI) of physical activity (PA) by domain, intensity and type. Rio Grande, Brazil, 2017 (N = 1294)



*Total coverage of variable in the census tract.

Fig. 2 Distribution of built, natural and social environment variables. Rio Grande, Brazil, 2017 (N = 1294)

Z score of the proportion of paved roads, the presence of curbs and the absence of open sewage increased by 22% (95% CI 1–49), 29% (95% CI 4–59), 6% (95% CI 1–12), respectively, the likelihood of individuals cycling for commuting. The absence of garbage accumulated in the streets and insecurity presented a borderline p value for association. After adjusting for the confounding factors, all variables were no longer associated with the practice of cycling for commuting, except for proximity to the seafront (76%, 95% CI 26–147%) and an increase in the Z score of the monthly income of the household head (13%; 95% CI 3–23%).

Discussion

The present study evaluated the influence of environmental factors on different modalities and intensities of PA during leisure time and commuting. There were few associations between the environment and the practice of PA, as well as inconsistencies in the findings within the same PA domain. Some characteristics of the environment (built, natural and social) significantly affected the practice of PA. Individuals who lived in places with private gyms and sports clubs, near the seafront, and with higher income were more likely to practice some type of PA.

Unexpectedly, the presence of private places for the practice of PA, such as sports clubs and gyms, was not associated with leisure-time PA in the present study. This may be explained by the fact that individuals do not go only to gyms near their residence, but elsewhere, which might have diluted this effect. The availability of places for the practice of PA near the household can stimulate such a behavior, thereby increasing the chances of individuals practicing PA during their leisure time (Gomes et al. 2016). However, individuals living near these places were more likely to walk. One possible hypothesis for this finding is that the locations with gyms have more infrastructure, with greater mixed use of the ground, hence stimulating active transport or more leisure-time PA (Villaça 2011).

Individuals living near the beach were found to be more active in commuting. One probable explanation is that the beach area is a place with less traffic of vehicles and a favorable landscape for the practice of PA. In this study, the distance from the sea was inversely related to the level of PA practice, especially walking, which is consistent with the literature (Kerr et al. 2014). In Brazil, a study with adolescents found an association between proximity to the seafront and a greater leisure-time PA practice (Silva et al. 2017). It is worth noting that Rio Grande has hundreds of kilometers of beach extension and is characterized by an immense seafront composed of a vast space of sand and a strip of dunes separating the beach from the resort town.

Here, the existence of public spaces was not associated with the practice of PA, contrary to what was expected. In contrast, a study carried out in Bogotá, Colombia (Gomez

Table 2 Crude and adjusted analysis (adjustment for the variables: gender, age, skin color, marital status, schooling, assets index, dwelling time in the neighborhood, environment variables contained in the table) of leisure-time physical activity (PA) with built, natural and social environmental variables in adults aged 18 years or more from the urban area of Rio Grande, Brazil, 2017

Characteristic	Walk at leisure (N = 1294)		Moderate to vigorous PA (MVPA) (N = 1293)	
	Crude PR (95% CI)	Adjusted PR (95% CI)	Crude PR (95% CI)	Adjusted PR (95% CI)
Demographic density	0.94 (0.81; 1.09)	1.08 (0.91; 1.29)	0.86 (0.75; 1.00)*	0.96 (0.82; 1.13)
Average monthly income of the head of the family of the sector	1.19 (1.04; 1.36)*	1.11 (1.02; 1.21)*	1.19 (1.07; 1.32)*	1.02 (0.95; 1.10)
Presence of parks and squares	0.89 (0.63; 1.25)	0.74 (0.53; 1.03)	0.88 (0.67; 1.15)	0.86 (0.65; 1.14)
Presence of hiking trails/bike paths	1.40 (1.02; 1.93)*	0.99 (0.70; 1.40)	1.16 (0.90; 1.51)	0.98 (0.74; 1.30)
Presence of cycle tracks	1.07 (0.73; 1.56)	1.43 (0.90; 2.28)	0.95 (0.63; 1.44)	1.38 (0.91; 2.08)
Presence of private gyms/sports clubs	1.35 (0.91; 1.99)	1.08 (0.79; 1.49)	1.02 (0.74; 1.41)	0.91 (0.69; 1.20)
Presence of public gyms	1.21 (0.85; 1.71)	0.95 (0.70; 1.28)	1.02 (0.77; 1.34)	0.99 (0.75; 1.32)
Number of bus stops	1.05 (0.90; 1.22)	1.02 (0.90; 1.16)	0.96 (0.84; 1.09)	1.02 (0.88; 1.18)
Proximity to the seafront	1.73 (1.29; 2.33)*	1.41 (0.84; 2.37)	1.69 (1.30; 2.20)*	1.16 (0.85; 1.58)
Proportion of street lighting	1.22 (1.00; 1.49)	1.06 (0.79; 1.42)	1.11 (0.94; 1.32)	0.99 (0.80; 1.22)
Proportion of paved streets	1.17 (1.00; 1.36)*	1.29 (0.80; 2.09)	1.10 (0.94; 1.29)	1.13 (0.81; 1.60)
Proportion of sidewalks	1.15 (0.98; 1.34)	0.94 (0.61; 1.44)	1.12 (0.96; 1.31)	1.03 (0.77; 1.38)
Curbs	1.10 (0.92; 1.32)	0.85 (0.68; 1.05)	1.11 (0.95; 1.29)	0.91 (0.74; 1.11)
Presence ramps for wheelchair	0.93 (0.79; 1.09)	0.97 (0.82; 1.14)	0.89 (0.77; 1.03)	0.96 (0.83; 1.11)
Manhole/uptake pipes	0.95 (0.80; 1.14)	0.94 (0.76; 1.16)	0.94 (0.79; 1.11)	1.00 (0.86; 1.18)
Proportion of afforestation	0.98 (0.83; 1.16)	0.95 (0.84; 1.07)	1.12 (0.97; 1.29)	1.07 (0.94; 1.23)
Proportion of nonexistent open sewage	1.41 (0.91; 2.19)	1.76 (0.82; 3.74)	1.12 (0.87; 1.43)	1.11 (0.62; 2.01)
Proportion of non-accumulated garbage on the streets	1.31 (0.98; 1.75)	0.70 (0.37; 1.34)	1.11 (0.87; 1.40)	0.88 (0.50; 1.55)
Insecurity	1.32 (1.10; 1.58)*	1.13 (0.96; 1.33)	1.24 (1.06; 1.45)*	**1.07 (0.93; 1.22)**

PR Prevalence ratio, *95% CI* 95% confidence interval, *MVPA* moderate to vigorous PA

*Associations with p value < 0.05

et al. 2010), with individuals aged 18 to 65 years, pointed out that the availability of public spaces for the practice of PA is important for the promotion of an active lifestyle in urban centers. Other studies with adult populations from different parts of the world have also reported a positive association between the availability of public places (Cerin et al. 2013; Hanibuchi et al. 2011), parks (Cauwenberg et al. 2017) and green areas (McCormack 2017) and the practice of leisure-time PA. The lack of association found in the present study can be explained by the scarce and uneven distribution of public spaces across the municipality of Rio Grande, with a higher concentration of PA-related spaces in higher-income areas, and by the poor quality of the few existing sites.

Census sectors with higher average income of the household head were associated with an increased likelihood of individuals riding bicycles for commuting and walking during their leisure time. In part, this finding is understandable, since wealthier people practice more PA during their leisure time (Beenackers et al. 2012). Nevertheless, occupational physical activities are more common among individuals with lower socioeconomic status (Beenackers et al. 2012). Individuals from higher-income census sectors may tend to ride bicycles for commuting more frequently because bicycle lanes are commonly located in downtown or in more developed neighborhoods.

It should be noted that all streets in the municipality of Rio Grande are predominantly flat, which is a "facilitator" of active transportation and leisure activities. A literature review carried out with the purpose of detecting the individual and environmental factors associated with bicycle usage by adults identified that the perception of traffic safety, appearance and infrastructure of the neighborhood, and access to bicycle lanes/paths were positively associated with bicycle usage. On the other hand, poor conditions and maintenance of these places as well as street inclination may decrease this practice (Kienteka et al. 2013). Studies in different countries have shown that living near walking paths and bicycle lanes/paths may encourage active

Table 3 Crude and adjusted analysis (adjustment for the variables: gender, age, skin color, marital status, schooling, assets index, dwelling time in the neighborhood, environment variables contained in the table) of commuting physical activity (PA) with built, natural and social environment variables in adults aged 18 years or more from the urban area of Rio Grande, Brazil, 2017

Characteristic	Walking (N = 1286)		Cycling movement (N = 1290)	
	Crude PR (95% CI)	Adjusted PR (95% CI)	Crude PR (95% CI)	Adjusted PR (95% CI)
Density demographic	1.05 (0.96; 1.16)	0.94 (0.83; 1.07)	0.91 (0.79; 1.06)	1.04 (0.90; 1.20)
Average monthly income of the head of the family of the sector	0.97 (0.91; 1.02)	0.95 (0.88; 1.01)	0.92 (0.71; 1.19)	1.13 (1.03; 1.23)*
Presence of parks and squares	1.19 (1.06; 1.34)*	1.04 (0.87; 1.24)	0.67 (0.46; 0.97)*	1.01 (0.71; 1.43)
Presence of hiking trails/bike paths	1.00 (0.87; 1.14)	0.95 (0.81; 1.12)	1.00 (0.76; 1.30)	1.21 (0.90; 1.63)
Presence of cycle tracks	1.09 (0.95; 1.25)	0.96 (0.80; 1.15)	0.90 (0.58; 1.39)	0.86 (0.53; 1.38)
Presence of private gyms/sports clubs	1.18 (1.04; 1.35)*	1.23 (1.08; 1.41)*	0.76 (0.56; 1.02)	0.94 (0.66; 1.33)
Presence of public gyms	0.99 (0.85; 1.15)	0.95 (0.80; 1.14)	0.72 (0.48; 1.06)	0.77 (0.54; 1.09)
Number of bus stops	1.01 (0.94; 1.09)	0.97 (0.89; 1.06)	1.02 (0.90; 1.16)	1.05 (0.92; 1.21)
Proximity to the seafront	0.87 (0.75; 1.00)	0.96 (0.79; 1.18)	1.35 (0.94; 1.93)	1.76 (1.26; 2.47)*
Proportion of street lighting	0.99 (0.91; 1.08)	0.95 (0.85; 1.08)	1.25 (0.95; 1.64)	1.16 (0.70; 1.92)
Proportion of paved streets	0.99 (0.92; 1.07)	0.98 (0.84; 1.15)	1.22 (1.01; 1.49)*	0.81 (0.33; 2.00)
Proportion of sidewalks	1.00 (0.92; 1.08)	1.15 (0.99; 1.34)	1.20 (0.99; 1.44)	0.77 (0.40; 1.49)
Curbs	0.97 (0.90; 1.04)	0.83 (0.73; 0.95)*	1.29 (1.04; 1.59)*	1.79 (0.85; 3.79)
Presence of ramps for wheelchair	1.04 (0.99; 1.09)	1.03 (0.97; 1.08)	1.00 (0.89; 1.13)	0.93 (0.82; 1.05)
Manhole/uptake pipes	1.02 (0.95; 1.08)	1.03 (0.93; 1.14)	1.13 (0.96; 1.34)	1.07 (0.83; 1.37)
Proportion of afforestation	1.03 (0.98; 1.09)	1.03 (0.97; 1.09)	1.04 (0.85; 1.26)	1.01 (0.82; 1.24)
Proportion of nonexistent open sewage	1.07 (1.01; 1.14)*	1.21 (0.85; 1.71)	1.06 (1.01; 1.12)*	0.85 (0.51; 1.45)
Proportion of non-accumulated garbage on the streets	1.07 (1.01; 1.13)*	0.94 (0.69; 1.29)	1.05 (1.00; 1.11)	1.04 (0.64; 1.69)
Insecurity	1.05 (0.98; 1.12)	1.06 (0.99; 1.13)	0.86 (0.73; 1.00)	0.92 (0.79; 1.06)

PR Prevalence ratio, *95% CI* 95% confidence interval

*Associations with p value < 0.05

commuting (Krizek and Johnson 2006; Tilahun et al. 2007). In the present study, however, no association was found between the presence of bicycle paths and walking for commuting. One hypothesis for that is the expressive number of individuals who own and/or use cars or motorcycles. For instance, two-thirds (66%) of the households in Rio Grande have motorized vehicles (car or motorcycle) and only a few bicycle lanes can be found across the city.

A significant negative association between neighborhood insecurity and the practice PA was expected, because in less secure areas people tend not to stay out on the streets and hence reduce the practice of outdoor or commuting PA (Corseuil et al. 2012). However, in the present study, a negative association was observed only for cycling for commuting, which was no longer significant following the adjusted analysis. It is important to emphasize that the data on safety were collected objectively, which differs from other studies (Florindo et al. 2011; Wood et al. 2008) using participants' perception/subjectivity, which may have affected the significance of the associations. Of note, subjective data may not accurately reflect the reality as they may be strongly related to previous experiences (Gebel et al. 2009). Nevertheless, recent evidence from a meta-analysis indicates that perceived safety of the neighborhood was related to the practice of PA (Rees-Punia et al. 2018). Here, our study showed that individuals who felt safe to walk around their houses were more likely to walk (data not shown).

Limitations

This study had some limitations that should be mentioned. The PA information was evaluated subjectively, which may lead to less accurate estimates; however, the research instrument used in this study was previously tested and presented satisfactory validity and reproducibility results (Craig et al. 2003). Another limitation is the existence of a possible minimized effect in the relationship between PA practice and the environment, since individuals can perform PA far from home, such as in places close to work, at school or in the university. Another important point is that

the distance from home to work was not questioned nor whether individuals had practiced PA in their neighborhood. In addition, the environment data were not obtained specifically for use in PA studies and, therefore, do not include qualitative information (e.g., quality of the squares).

The presence of household selection bias should also be considered, given that people choose where to live based on their financial conditions and personal preferences (Cao, 2014). Therefore, it is possible that some individuals are physically active because the built environment close to their homes is more conducive to the practice of PA, or because those who practice PA generally tend to choose neighborhoods that allow them to engage in such a behavior (Calise et al. 2013). The cross-sectional design limits the temporal inference of the associations between environmental variables and PA, which may be useful to determine reverse causality. However, longitudinal studies are needed to determine whether there is a cause–effect relationship involved. Lastly, there was a time gap between data collection (2016) and georeferencing (2017) using the IBGE (2011) data (e.g., paving, density, street lighting, curbs, accessibility features), although environmental measures are usually stable.

Strengths

The strengths of this study include sample representativeness of a municipality in the southern Brazil, which allows for the extrapolation of results to other locations with similar characteristics. Another relevant point was the expressive number of environmental variables analyzed and their relationship with the different intensities and modalities of PA. Of note, the leisure-time and commuting PA measures were analyzed separately (which could not be performed using an accelerometer), differing from other studies in the field. The adoption of objective measurements, such as GPS data to georeference households and the measurements obtained from GIS, is also positive point to highlight. Unlike subjective perceived data, objective measurements are accurate to describe the distance between the household and specific destinations such as parks, stores, gyms (Brownson et al. 2009; Hino et al. 2010).

Conclusions

The promotion of PA practice is a public health priority in Brazil and worldwide and requires the adoption of urgent, comprehensive and effective interventions. This study provides evidence on the lack of association between objective environmental measures and the practice of PA. Although there were few significant results and inconsistencies in the intensity and modalities of PA within the same domain, some environmental variables (e.g., proximity to the beach, presence of private gyms and sports clubs, and higher average income) were associated with a more frequent practice of PA. The lack of associations may be due to the scarcity of public places to engage in PA practice, such as bicycle lanes or outdoor gyms. Further studies addressing workplace, school and university settings, not just households, are encouraged to encompass the diversity of locations where individuals can potentially perform PA. From a longitudinal standpoint, cohort studies or natural experiments should be carried out to determine whether changes in the built, natural or social environment could affect the practice of PA.

Authors' contribution JLB performed the data analysis and drafted the manuscript. RGP supervised the collection of data and critically reviewed the article. SCD conceived the study and critically reviewed the article. All authors approved the final version of the manuscript.

Funding This study was supported by Foundation for Research Support of the State of Rio Grande do Sul (FAPERGS), Grant ARD/PPP/2014, Application No. 16/2551-0000359-9.

Compliance with ethical standards

Conflict of interest The authors declare no conflict of interest.

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.

References

Bauman AE, Reis RS, Sallis JF, Wells JC, Loos RJF, Martin BW (2012) Correlates of physical activity: why are some people physically active and others not? Lancet 380:258–271

Beenackers MA, Kamphuis CB, Giskes K, Brug J, Kunst AE, Burdorf A, van Lenthe FJ (2012) Socioeconomic inequalities in occupational, leisure-time, and transport related physical activity among European adults: a systematic review. Int J Behav Nutr Phys Act 9:116

Brownson RC, Hoehner CM, Day K, Forsyth A, Sallis JF (2009) Measuring the built environment for physical activity: state of the science. Am J Prev Med 36:S99–S123

Calise TV, Heeren T, DeJong W, Dumith SC, Kohl HW III (2013) Peer reviewed: do neighborhoods make people active, or do people make active neighborhoods? Evidence from a planned community in Austin, Texas. Prev Chronic Dis 10:120119

Cao X (2014) Residential self-selection in the relationships between the built environment and travel behavior: introduction to the special issue. J Transp Land Use 7:1–3

Cauwenberg JV, Cerin E, Timperio A, Salmon J, Deforche B, Veitch J (2017) Is the association between park proximity and recreational physical activity among mid-older aged adults moderated by park quality and neighborhood conditions? Int J Environ Res Public Health 14:192

Cerin E, Lee KY, Barnett A, Sit CH, Cheung MC, Chan WM (2013) Objectively-measured neighborhood environments and leisure-time physical activity in Chinese urban elders. Prev Med 56:86–89

Corseuil WM, Hallal PC, Xavier Corseuil H, Schneider IJC, D'orsi E (2012) Safety from crime and physical activity among older adults: a population-based study in Brazil. J Environ Public Health 2012:1–7

Craig CL, Marshall AL, Sjostrom M, Bauman AE, Booth ML, Ainsworth BE (2003) International Physical Activity Questionnaire: 12-country reliability and validity. Med Sci Sports Exerc 35:1381–1395

Ding D, Adams MA, Sallis JF, Norman GJ, Hovell MF, Chambers CD, Gomez LF (2013) Perceived neighborhood environment and physical activity in 11 countries: Do associations differ by country? Int J Behav Nutr Phys Act 10:57

Dumith SC, Hallal PC, Reis RS, Kohl HW (2011) Worldwide prevalence of physical inactivity and its association with human development index in 76 countries. Prev Med 53:1–24

Dumith SC, Paulitsch RG, Carpena MX, Murano MFR, Simões MO, Machado KP, Duas MS, Kretschmer AC, Oliz MM, Pontes LS, Susin LRO (2018) Planning and execution of a population health survey by means of a multidisciplinary research consortium. Sci Med 28:3

Filmer D, Pritchett LH (2001) Estimating wealth effects without expenditure data—or tears: an application to educational enrollments in states of India. Demography 38:115–132

Florindo AA, Salvador EP, Reis RS, Guimaraes VV (2011) Perception of the environment and practice of physical activity by adults in a low socioeconomic area. Rev Saude Publica 45:302–310

Garber CE, Blissmer B, Deschenes MR, Franklin BA, Lamonte MJ, Lee IM, Swain DP (2011) Quantity and quality of exercise for developing and maintaining cardiorespiratory, musculoskeletal, and neuromotor fitness in apparently healthy adults: guidance for prescribing exercise. Med Sci Sports Exerc 43:1334–1359

Gebel K, Bauman A, Owen N (2009) Correlates of non-concordance between perceived and objective measures of walkability. Ann Behav Med 37:228–238

Gomes CS, Matozinhos FP, Mendes LL, Pessoa MC, Velasquez-Melendez G (2016) Physical and social environment are associated to leisure time physical activity in adults of a Brazilian city: a cross-sectional study. PLoS ONE 11:e0150017

Gomez LF, Sarmiento OL, Parra DC, Schmid TL, Pratt M, Jacoby E, Ardila M (2010) Characteristics of the built environment associated with leisure-time physical activity among adults in Bogotá, Colombia: a multilevel study. J Phys Act Health 7:196–203

Hallal PC, Andersen LB, Bull FC, Guthold R, Haskell W, Ekelund U, Lancet Physical Activity Series Working Group (2012) Global physical activity levels: surveillance progress, pitfalls, and prospects. The Lancet 380:247–257

Hanibuchi T, Kawachi I, Nakaya T, Hirai H, Kondo K (2011) Neighborhood built environment and physical activity of Japanese older adults: results from the Aichi Gerontological Evaluation Study (AGES). BMC Public Health 11:657

Hino AA, Reis RS, Florindo AA (2010) Ambiente construído e atividade física: uma breve revisão dos métodos de avaliação. Rev Bras Cineantropom. Desempenho Hum 12:387–394

Instituto Brasileiro de Geografia e Estatística (IBGE) (2011) Censo Demográfico 2010: Características da População e dos domicílios: Resultados. IBGE, Rio de Janeiro

Kerr J, Norman G, Millstein R, Adams MA, Morgan C, Langer RD, Allison M (2014) Neighborhood environment and physical activity among older women: findings from the San Diego Cohort of the Women's Health Initiative. J Phys Act Health 11:1070–1077

Kienteka M, Fermino RC, Reis RS (2013) Fatores individuais e ambientais associados com o uso de bicicleta por adultos: uma revisão sistemática. Rev Bras de Ativ Fís e Saúde 19:12

Krizek K, Johnson P (2006) Proximity to trails and retail: effects on urban cycling and walking. J Am Plan Assoc 72:33–42

Lee IM, Shiroma EJ, Lobelo F, Puska P, Blair SN, Katzmarzyk PT (2012) Effect of physical inactivity on major non-communicable diseases worldwide: an analysis of burden of disease and life expectancy. Lancet 380:219–229

Macintyre S, Ellaway A, Cummins S (2002) Place effects on health: how can we conceptualise, operationalise and measure them? Soc Sci Med 55:125–139

Matsudo S, Araujo T, Marsudo V, Andrade D, Andrade E, Braggion G (2001) Questionário internacional de atividade física (IPAQ): estudo de validade e reprodutibilidade no Brasil. Rev Bras de Ativ Fís e Saúde 6:05–18

McCormack GR (2017) Neighbourhood built environment characteristics associated with different types of physical activity in Canadian adults. Health Promot Chronic Dis Prev Can 37:175–185

Rees-Punia E, Hathaway ED, Gay JL (2018) Crime, perceived safety, and physical activity: a meta-analysis. Prev Med 111:307–313

Sallis JF, Cervero RB, Ascher W, Henderson KA, Kraft MK, Kerr J (2006) An ecological approach to creating active living communities. Annu Rev Public Health 27:297–322

Sallis JF, Cerin E, Conway TL, Adams MA, Frank LD, Pratt M, Davey R (2016) Physical activity in relation to urban environments in 14 cities worldwide: a cross-sectional study. Lancet 387:2207–2217

Silva ICM, Hino AA, Lopes A, Ekelund U, Brage S, Gonçalves H, Hallal PC (2017) Built environment and physical activity: domain-and activity-specific associations among Brazilian adolescents. BMC Public Health 17:616

Sugiyama T, Neuhaus M, Cole R, Giles- Corti R, Owen N (2012) Destination and route attributes associated with adults' walking: a review. Med Sci Sports Exerc 44:1275–1286

Tilahun NY, Levinson DM, Krizek KJ (2007) Trails, lanes, or traffic: valuing bicycle facilities with an adaptive stated preference survey. Transp Res Part A Policy Pract 41:287–301

Vigitel Brazil 2017: surveillance of risk and protective factors for chronic diseases by telephone survey: estimates of Frequency and sociodemographic distribution of risk and protective factors for chronic diseases in the capitals of the 26 Brazilian states and the Federal District in 2017. Brazilian: Ministry of Health, Secretariat of Health Surveillance, Department of Surveillance of Diseases and Non-Communicable Diseases and Health Promotion 2018

Villaça F (2011) São Paulo: segregação urbana e desigualdade. Estudos avançados 25:37–58

Wendel-Vos W, Droomers M, Kremers S, Brug J, Van Lenthe F (2007) Potential environmental determinants of physical activity in adults: a systematic review. Obes Rev 8:425–440

Wood L, Shannon T, Bulsara M, Pikora T, McCormack G, Giles-Corti B (2008) The anatomy of the safe and social suburb: an exploratory study of the built environment, social capital and residents' perceptions of safety. Health Place 14:15–31