Built and Social Environment by Systematic Social Observation and Leisure-Time Physical Activity Report among Brazilian Adults: a Population-Based Study

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Abstract The aim of this study was to investigate the relationship between built and social environment and leisure-time physical activity (LTPA) among adults living in an urban center. The individual data was from the household survey and the environmental data was assessed through systematic social observation by trained observers on street segments of respondents' residences. The relationship between environmental factors and LTPA was examined using multilevel logistic regression. The prevalence of LTPA was 30.2% (95% CI 27.4–32.9%). Individuals living in census tracts with higher walking environment indicators (OR = 1.20; 95% CI 1.02 to 1.40) and safety (OR = 1.18; 95% CI 1.01 to 1.38) were more likely to be active during leisure time, even after adjusting for individual variables. Improving the built and social environment is an important step for achieving higher levels of LTPA in the population in a middle-income country.

Keywords Environment and health · Physical activity · Environment · Systematic social observation

Introduction

Ecological models are often used to address the multifactorial aspect of physical activity, with particular emphasis on the physical and social environment [1, 2]. These models assume that the practice of a physical activity is influenced by proximal and distal factors, for example, intrapersonal, interpersonal, community, and social or cultural, operating at multiple levels. Today, more than half the world population lives in urban areas, a proportion that is expected to increase to more than 70% by 2025 [3]. In times of low levels of leisure-time physical activity [4, 5] and growing urbanization, understanding the role of the environment in an active lifestyle is vital.

The investigation of relations between physical activity and the environment involves a number of methodological challenges. The environmental factors can be measured in different ways, including perception-based approaches, objective methods such as auditing and systematic social observation, and geographic information systems. Few systematic social observation studies

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have been published to date, particularly in low- and middle-income countries [6, 7]. Systematic social observation refers to direct observation of physical conditions and social interactions in the household [8].

Evidences concerning the relationship between physical activity and the environment are derived from high-income countries. In Brazil, in spite of a growing number of studies, objective environmental assessment has been seldom reported [9–11]. Also, the urban environment in Brazil and Latin America differs from that of the USA and Australia in terms of population density, transportation, and social and environmental iniquities [3, 12].

This study was set out to investigate the associations between leisure-time physical activity and objective measures of built and social environments, using systematic social observation of residents of an urban center.

Methods

Data used in this study were obtained from a multimethod epidemiological study involving household surveys (*Saúde em Beagá*; 2008–2009) and objective environment characterization based on systematic social observation (2011), both carried out by Observatory Urban Health of Belo Horizonte (OSUBH) at the Federal University of Minas Gerais. Two out of nine Health Districts of Belo Horizonte (*Oeste* and *Barreiro*) were included. Combined, these districts account for 24% of the 2,375,151 city residents [13]. These districts were selected due to geographical proximity and relevant internal heterogeneity along several demographic, socioeconomic, and health indicators reflecting social and health inequities in the city [14, 15].

Saúde em Beagá included resident adults selected using stratified probability sampling and three-stage cluster sampling, as follows: (a) census tracts selected with unequal probability and sample size proportional to the total number of census tracts in the stratum ($n = 149$); (b) household selected by simple random sampling of households registered in the database of the City Administration of Belo Horizonte ($n = 4,048$); (c) one adult resident (18 years old or above), adding up to 4048 adult individuals [14]. A health vulnerability index (HVI) geocoded by census tract was used as a stratifying factor to ensure proportionate representation of all levels of socioeconomic status in the sample. The HVI was

developed by the Municipal Health Department of Belo Horizonte and encompasses sanitation, housing, income, and social domains [16].

The systematic social observation was designed and carried out by independent observers in the same geographical area of the study. Units of analysis corresponded to street segments within 100-m range, in any direction, from the households of survey respondents. Segments were defined according to respondents' perception of neighborhood boundaries as "closest households, in the same building or streets" or "to the end of this block" in more than 50% of cases, bearing in mind the typical, 100-m-long Belo Horizonte city block [15, 17, 18].

Grouped segments within a census tract were defined as neighborhoods belonging to that particular census tract; this resulted in 149 neighborhoods (2010 Demographic Census). Census tracts were combined into a single neighborhood in the following cases (two census tracts respectively): households belonging to different tracts but located in the same street and census tracts taken as a single tract at the time of survey (2008–2009; 2000 Demographic Census). Once neighborhood segments had been determined, a systematic sampling system (segments per census tract) was defined. The final sample comprised 1,295 segments grouped into 147 census tracts. Segment length ranged from 50 to 250 m (100 m on average). Details on the method have been published previously [15, 17].

An instrument was then created to determine and quantify neighborhood physical and social environment characteristics potentially associated with health-related events. This instrument comprised the following domains: physical, social, physical activity, building characteristics, aesthetic, services, and safety [15, 17]. Instrument reliability had been assessed in a previous study and was thought adequate for items with greater temporal stability, particularly services, building characteristics, physical *pedestrian environment*, and safety [15].

Data collection per segment was performed by pairs of observers, altered daily in their composition at random. Each observer filled out a section of the instrument, allowing communication between them. The observer received a map containing the location of the segment, with specifications of the beginning and end of the segment and its side A and B.

The processes of neighborhood definition and segment manipulation and sampling were performed using MapInfo software, version 8.5 (MapInfo Corp., New

York, USA), for visualization and manipulation; and Google Earth, version 5.1.3535.3218 (Google Inc., Mountain View, United States), for updating and correcting road network. The fixing of 100 m from the address for the access segments was carried out in software R, version 2.11.0 a (the R Foundation for Statistical Computing, Vienna, Austria, http://www.r-project.org).

Outcome Variable

Physical activity was measured using the long version of the International Physical Activity Questionnaire; time spent in physical activities per week was assessed across different domains [19]. Leisure-time physical activity corresponded to the product of frequency (days/week) and average duration (minutes/day) of walking and mild, moderate, or vigorous activities (the latter multiplied by two). Only continuous activities lasting 10 min or more were considered. Individuals with physical activity scores ≥ 150 min/week were defined as active [20].

Individual Variables

The following variables were considered: age (years), sex (male or female), current occupation (yes/no), marital status (with a partner: married/de facto relationship, or with no partner: single/divorced/widow), and time of residence (years). The socioeconomic status (low, middle, or high, divided into tertiles) was measured at the individual level and built up based on the information on household goods consumption and the schooling of the head of the household [21].

Context Variables

Objective environmental variables were derived from composite indicators based on the systematic social observation data and grouped by census tract. First, simple indicators were created for the 147 census tracts using ratio estimators; these corresponded to mean ratio estimates of items observed per household within a segment and the average proportion of segments containing a given characteristic. Simple indicators were then grouped into domains, and new indicators constructed for each domain using principal component analysis with covariance matrix. The domains proposed had acceptable internal consistency (Cronbach's alpha,

0.591 to 0.820). Further details on indicator construction can be found in a previous study [17].

The following domains and respective items were included in this study: *Walking environment*—sidewalk paving, trees for shading, sidewalk width at the smaller extremity, and favorable perception for walking. *Spaces for physical activity and leisure*—presence of spaces and facilities for physical activity, presence of parks and squares, and favorable perceptions of the physical activity environment. *Aesthetic quality*—political advertisement, presence of trees and gardens, cleanness of the environment, and presence of nuisance noise. *Physical disorder*—trash (needles, cigarettes, tin, and condoms) and presence of graffiti in public equipment. *Safety*—public lighting, safety items, and police surveillance. *Services*—grocery stores, public or private health facilities, and public or private gyms. Scale items were scored zero to five. High scores reflect a positive environmental assessment, with the exception of the *physical disorder* scale, to which the opposite interpretation applies.

Statistical Analysis

Descriptive data analysis was performed. Categorical variables were expressed as proportions, and continuous variables as means, medians, standard deviations (SD), and interquartile ranges (IQR). Adjusted multilevel logistic regression models were used, where first and second levels corresponded to individuals and census tracts (neighborhoods), respectively. All models were fitted with random intercepts. Intraclass correlation coefficients were estimated using the latent variable method [22].

First, a null hypothesis model (random intercept only) was adjusted to assess the effect of context. Simple multilevel logistic regression was then applied to individual environmental variables (*walking environment*, *spaces for physical activity and leisure*, *aesthetic quality*, *physical disorder*, *safety*, and *services* scales). Variables with $p \leq 0.20$ were entered in a multiple regression analysis and those with $p \leq 0.05$ retained. Finally, individual characteristics were included as adjustment variables.

The level of significance was set at 5%. Analyses were performed using STATA software (Stata Corporation, College Station, Texas) version 12.0; prevalence estimates were calculated using the *svy* command to account for complex sample design. Multilevel models

were adjusted to sampling weights. Geographic data were processed using software (ArcGis 10.3; http://www.esri.com/software/arcgis/index.html).

This study was approved by the Research Ethics Committee of *Universidade Federal de Minas Gerais* (ETIC 253/06). Participants signed an informed consent form.

Results

This study comprised 3,815 individuals living in 147 neighborhoods (233 individuals were excluded due to lack of information on the outcome variable). Mean participant age and time of residence were 41.1 (± 16.0) and 15.4 (± 12.5) years, respectively. Most participants were women (53.1%), reported living with a partner (53.2%), and employed at the time of study (64.8%), in the low to middle socioeconomic status (59.2%). The overall prevalence of leisure-time physical activity was 30.2% (95% CI 27.3–33.1), with higher prevalence among male, without partners, young adults, with higher socioeconomic status, and shorter time of residence. No significant associations with current occupation were observed (Table 1).

The distribution of *walking environment*, s*paces for physical activity and leisure*, *aesthetic quality*, *physical disorder*, *safety*, and *services* scales is presented in Table 2. *Spaces for physical activity and leisure* and *services* scales had the lowest means, suggesting low frequency of these environmental attributes in the study area. Similar findings can be appreciated in thematic maps displaying the spatial distribution of attributes assessed across different scale domains (Fig. 1).

Univariate analysis revealed significant positive associations between leisure-time physical activity and *walking environment*, *aesthetic quality*, and *safety* scales (Table 3). Four models were adjusted for multiple analysis, as follows: null hypothesis model, indicating significant variability in leisure-time physical activity between census tracts; model 1, adjusted for *walking environment*, *safety*, and *aesthetic quality* scales (only the first two were significant); model 2, adjusted for *walking environment* and *safety* scales; model 3, adjusted for *walking environment* and *safety* scales, and individual variables (age, sex, marital status, current occupation, time of residence, and socioeconomic status). *Walking environment* and *safety* scales remained significant in models 2 and 3. Individuals living in neighborhoods with higher walking environment (OR = 1.20; 95% CI

Table 1 Description of individual characteristics and association with leisure physical activity (n = 3,815 individuals). Belo Horizonte, 2008–2011

Variables	Total	Leisure-time physical activity		p value
		Active	Inactive	
	% or mean (CI 95%)	% or mean (CI 95%)	% or mean (CI 95%)	
Sex (%)				
Male	46.9 (44.3–49.5)	36.2 (31.5–40.8)	63.8 (59.2–68.4)	< 0.001
Female	53.1 (50.5–55.7)	24.9 (21.8–28.1)	75.1 (71.9–78.1)	
Current occupation (%)				
Yes	64.8 (62.7–66.9)	30.7 (26.7–34.7)	69.3 (65.3–73.3)	0.968
No	35.2 (33.1–37.3)	30.0 (26.7–33.2)	70.0 (66.8–73.2)	
Marital status (%)				
With no partner	46.8 (44.4–49.1)	34.2 (30.3–38.1)	65.8 (61.9–69.6)	0.001
With a partner	53.2 (50.8–55.5)	26.7 (23.3–30.0)	73.3 (70.0–76.7)	
Socioeconomic status (%)				
Low	26.8 (24.0–29.6)	20.2 (16.1–24.2)	79.8 (75.7–83.9)	< 0.001
Middle	32.4 (30.1–34.6)	25.4 (21.9–28.9)	74.6 (71.1–78.1)	
High	40.8 (37.5–44.0)	40.6 (54.4–64.3)	59.4 (54.4–64.3)	
Age (mean)	41.1 (40.3–41.8)	38.6 (37.4–39.8)	42.1 (41.3–43.0)	< 0.001
Time of residence (mean)	15.4 (14.7–16.2)	14.4 (15.0–16.6)	15.8 (13.3–15.5)	0.048

CI 95%, 95% confidence interval

Table 2 Description of the characteristics of the built and social environment (*n* = 147 neighborhoods). Belo Horizonte, 2008–2011

	Walking environment[a]	Space for physical activity and leisure[b]	Aesthetic quality[c]	Physical disorder[d]	Safety[e]	Services[f]
n (%)						
0.0–1.0	12 (8.2)	117 (79.7)	77 (52.3)	15 (10.2)	66 (44.9)	136 (92.5)
1.1–2.0	23 (15.7)	14 (9.5)	14 (9.5)	82 (55.8)	46 (31.3)	9 (6.1)
2.1–3.0	50 (34.0)	10 (6.8)	17 (11.6)	37 (25.2)	21 (14.3)	1 (0.7)
3.1–4.0	48 (32.6)	3 (2.0)	27 (18.4)	10 (6.8)	9 (6.1)	0 (0.0)
4.1–5.0	14 (9.5)	3 (2.0)	12 (8.2)	3 (2.0)	5 (3.4)	1 (0.7)
Mean (SD)	2.8 (1.0)	0.7 (1.0)	1.6 (1.4)	1.8 (0.8)	1.5 (1.2)	0.6 (0.5)
Median (IQR)	2.8 (0.7)	0.2 (0.2)	1.0 (0.5)	1.7 (0.4)	1.2 (1.2)	0.5 (0.1)

SD, standard deviations; *IQR*, interquartile ranges

[a] Sidewalk paving, trees for shading, sidewalk width at the smaller extremity, and favorable perception for walking

[b] Presence of spaces and facilities for physical activity, presence of parks and squares and favorable perceptions of the physical activity environment

[c] Political advertisement, presence of trees and gardens, cleanness of the environment, and presence of nuisance noise

[d] Trash (needles, cigarettes, tin, and condoms) and presence of graffiti in public equipment

[e] Public lighting, safety items, police surveillance

[f] Grocery stores, public or private health facilities, and public or private gyms

1.02–1.40) and safety (OR = 1.18; 95% CI 1.01–1.38) indicators had higher odds of being physically active, even after adjustment for individual variables (Table 4).

Discussion

This study set out to investigate whether leisure-time physical activity is associated with the built and social environment as measured by systematic social observation. Individuals living in neighborhoods with higher *walking environment* and *safety* indicators were more likely to be active during leisure time, even after adjustment for individual variables.

The *walking environment* scale comprised items related to sidewalk paving, trees for shading, sidewalk width at the smaller extremity, and favorable perception for walking. Scale attributes reflect neighborhood characteristics that may improve pedestrian experience or support urban design guidelines aimed to promote walking and other physical activities. Footpaths are the most basic environmental attributes for engaging in leisure physical activities and walking and may be altered using simple and inexpensive strategies [23].

A study involving 909 American adults and systematic social observation-based measurements of environmental attributes revealed positive associations between

physical activity levels and sidewalk conditions [24]. In a second American study based on the mini-version of the Microscale Audit of Pedestrian Streetscape (MAPS-Mini), items such as sidewalk, curb ramps, lighting, seats, and road verges were positively associated with walkability [23]. Similar findings were reported in Brazilian studies evaluating the availability of pedestrian lanes, traffic lights, street lamps, sidewalk, and sidewalk wider than 1 m using a streetscape audit tool [11] or perceived measures of sidewalk availability and quality [25, 26].

Items in the *safety* scale (public lighting, safety items, and police surveillance) were associated with leisure-time physical activity in this study. The scale items reflect neighborhood characteristics associated with surveillance, control mechanisms, and reduced exposure to crime [27], all of which may contribute to reduce disorder, uncivil activities, crime fear, or even criminal opportunities in the neighborhood [28].

National and international studies investigating safety attributes via subjective measurements have shown that individuals perceiving their neighborhood as safe or crime free tend to be more active [10, 29]. Positive associations between physical activity and official crime statistics have been reported, including homicide rates [30], violence indicators [31], and crime rates [32]. However, Australian studies evaluating leisure and
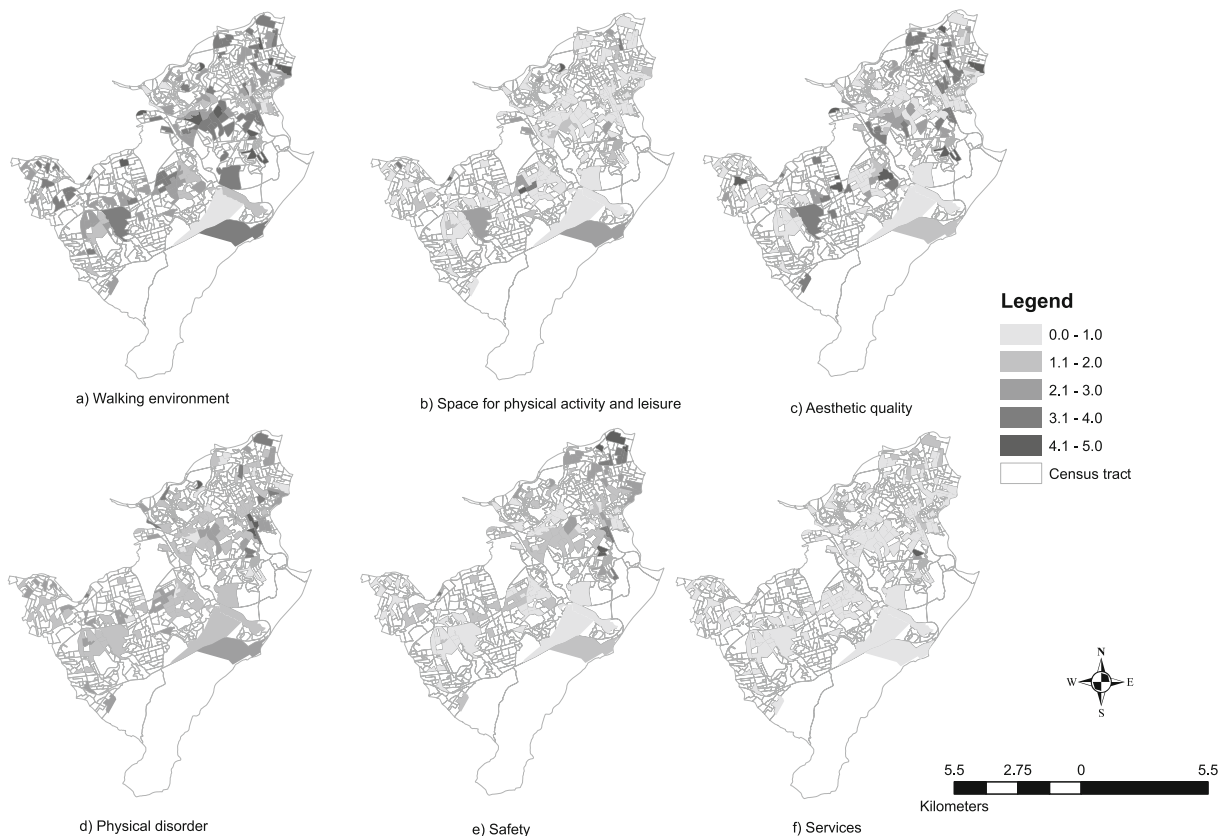
Fig. 1 Spatial distribution of the walking environment, space for physical activity and leisure, aesthetic quality, physical disorder, safety and services scales. Belo Horizonte, 2008–2011

commuting walking failed to reveal associations with street lighting and house surveillance as measured by auditing methods [33].

Associations between neighborhood safety and physical activities are not a consensus in literature [34–36]. Different attribute measurement methods may explain discrepancies between studies [29]. In spite of disputable findings, results are relevant for middle- and low-income countries where lack of safety and rising crime rates resulting from rapid urbanization may limit walkability and leisure physical activity [9, 29]. Feelings of unsafety and fear of crime may lead people to avoid certain places or streets or move to a different neighborhood or even result in social alienation and mistrust [28].

In studies carried out in high-income countries, aesthetic attributes were weakly associated with physical activity [35, 37]. Similar to this study, previous perception surveys and environmental audits failed to describe associations between physical activity and aesthetic attributes [25, 33, 38, 39]. This may have reflected lack of heterogeneity of aesthetic attributes in the neighborhoods

studied. More than half the census tracts in this sample scored between zero and one in the *aesthetic* scale.

As in this case, studies based on perceived and objective measures of *physical disorder* failed to detect associations with physical activity or specific behaviors [24, 40–43]. This is particularly true when comparing with the study carried out by [41]. The authors developed a similar physical disorder indicator, and they failed to show associations with leisure-time walking or physical activity.

Items in the s*ervices* scales (grocery stores, private and public health facilities, and public or private gyms) were not associated with leisure-time physical activities in this study. Availability of such establishments as measured by auditing was also not associated with physical activity in a previous Australian study [33]. However, there are evidences to suggest that areas with wider availability of commercial establishments, public services or sports, and leisure facilities tend to be more appealing and therefore conducive to physical activity [1, 11, 35, 39, 44]. Lack of associations in this study

Table 3 Unadjusted association between leisure-time physical activity and characteristics of the built and social environment. Belo Horizonte, 2008–2011

Variables	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)	OR (CI 95%)
Walking environment[a]	1.42 (1.25–1.63)*					
Space for physical activity and leisure[b]		1.02 (0.89–1.16)				
Aesthetic quality[c]			1.17 (1.04–1.30)*			
Physical disorder[d]				0.97 (0.78–1.19)		
Safety[e]					1.39 (1.21–1.60)*	
Services[f]						1.19 (0.95–1.50)
Variance (standard error)	0.40 (0.10)	0.52 (0.12)	0.47 (0.12)	0.51 (0.12)	0.40 (0.10)	0.51 (0.12)
Intraclass correlation	10.98	13.56	12.57	13.54	10.78	13.40

OR, odds ratio; CI 95%, 95% confidence interval

*$p < 0.05$

[a] Sidewalk paving, trees for shading, sidewalk width at the smaller extremity, and favorable perception for walking

[b] Presence of spaces and facilities for physical activity, presence of parks and squares, and favorable perceptions of the physical activity environment

[c] Political advertisement, presence of trees and gardens, cleanness of the environment, and presence of nuisance noise

[d] Trash (needles, cigarettes, tin, and condoms) and presence of graffiti in public equipment

[e] Public lighting, safety items, police surveillance

[f] Grocery stores, public or private health facilities, and public or private gyms

Table 4 Analysis adjusted by multilevel logistic regression for leisure-time physical activity and characteristics of the built and social environment. Belo Horizonte, 2008–2011

Variables	Null model[1] OR (CI 95%)	Model 1[2] OR (CI 95%)	Model 2[2] OR (CI 95%)	Model 3[3] OR (CI 95%)
Walking environment[a]	–	1.25 (1.07–1.45)*	1.25 (1.08–1.46)*	1.20 (1.02–1.40)*
Safety[b]	–	1.23 (1.06–1.44)*	1.24 (1.06–1.45)*	1.18 (1.01–1.38)*
Aesthetic quality[c]	–	1.02 (0.91–1.13)	–	–
Variance (standard error)	0.53 (0.13)	0.38 (0.10)	0.38 (0.10)	0.35 (0.09)
Intraclass correlation	13.96	10.36	10.36	9.56

[1] Null model (random intercept)

[2] Adjusted by the variables of the environment

[3] Adjusted by the variables of the environment, age, sex, marital status, current occupation, time of residence and socioeconomic status; OR, odds ratio; CI 95%, 95% confidence interval; *$p < 0.05$

[a] Sidewalk paving, trees for shading, sidewalk width at the smaller extremity, and favorable perception for walking

[b] Presence of spaces and facilities for physical activity, presence of parks and squares, and favorable perceptions of the physical activity environment

[c] Political advertisement, presence of trees and gardens, cleanness of the environment, and presence of nuisance noise

[d] Trash (needles, cigarettes, tin, and condoms) and presence of graffiti in public equipment

[e] Public lighting, safety items, police surveillance

[f] Grocery stores, public or private health facilities, and public or private gyms

may have been due to the low frequency of such attributes in the study area, where 92.5% of census tracts scored zero to one in the *services* scales.

Associations between leisure-time physical activity and availability of spaces for physical activity have been extensively reported [25, 36, 39, 44–51]. Lack of significant associations in this study may have reflected methodological differences or the low frequency of such attributes in the study area. Besides, data collection strategies in this study excluded the availability of such places in neighboring census tracts or within walking distance.

Physical activity was not associated with items in the *space for physical activity and leisure*, *aesthetic quality*, *physical disorder*, and *services* scales in this study. The fact that physically active individuals may undertake physical activities elsewhere may have significantly impacted this statistical analysis [36, 42]. Determining the place of practice is therefore vital for improved understanding of the relations between environmental factors and physical activity [51].

Results of this study must be interpreted in the light of methodological issues beyond cross-sectional study design. Neighborhood boundaries were determined according to census tracts and may not have reflected respondents' perception of neighborhood in the geographical sense [18]. Measuring attributes via systematic social observation may have been limiting in some cases, given certain items are subject to temporal variation [15]. Data in this study refer exclusively to two out of nine health districts in the city and may therefore not be representative of the whole population of Belo Horizonte; still, contrasts and iniquities of a large urban center were potentially addressed, as intended by the sample design adopted. Self-report measures of leisure-time physical activity are subject to under- or overestimation regarding duration and intensity. Finally, external comparison for this study's results was difficult due to the predominance of studies carried out in high-income countries, which may not be comparable to the Brazilian context.

Assessing the attributes of the environment has been a challenge since, despite the conceptual simplicity, its operationalization depends on territorial cuts and the possibility of collecting primary or secondary data. The environment can be measured from perception, systematic social observation, or geoprocessing data. Future studies involving a combination of subjective and objective measurements of environmental variables are warranted. The combined use of geographical data and data derived from systematic social observation is also advisable, particularly where the qualitative and quantitative assessment of places for physical activity is concerned.

However, the value of systematic social observation as a valid, reliable, and independent tool to assess social and physical environmental characteristics must be emphasized [17]. Systematic social observation allows the collection of quantitative and qualitative data within a single investigation. The instrument employed in this study was validated for the same population and thought appropriate to assess characteristics pertaining to the everyday life context of respondents [15]. The study presented a favorable sample size and sampling design for the proposed analyses. Also, multilevel analysis permits variance estimation at different hierarchical levels and is well suited for hypothesis construction in studies investigating contextual roles [22].

Associations described in the study suggest that walking environment and safety-related attributes may positively impact leisure-time physical activity in adults living in middle-income countries. The following investments are warranted to promote recommended levels of physical activity: improved quality of sidewalks and other pedestrian-oriented attributes and safety measures such as street lighting, public space revitalization, creation of communal areas, and police surveillance. Such environmental aspects should be incorporated into public urban planning policies to contemplate the need to provide city dwellers with environments conducive to physical activity.

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