Which physical and social characteristics of Brazilian cities contribute to physical activity of adolescents?

Quais características físicas e sociais das cidades brasileiras contribuem para atividade física de adolescentes?

Juliana Ilídio da Silva (https://orcid.org/0000-0002-0604-6662) [1]
Luciano Antonacci Condessa (https://orcid.org/0000-0002-3451-8639) [2]
Dário Alves da Silva Costa (https://orcid.org/0000-0002-5959-0370) [2]
Fabiano de Almeida Célio (https://orcid.org/0000-0003-4731-8617) [3]
Deborah Carvalho Malta (https://orcid.org/0000-0002-8214-5734) [4]
Amanda Cristina de Souza Andrade (https://orcid.org/0000-0002-3366-4423) [1]
Waleska Teixeira Caiaffa (https://orcid.org/0000-0001-5043-4980) [2]

Abstract *This study aimed to analyze the association between adolescents' physical activity and the Brazilian capitals' built and social environment. The units of analysis of this ecological study were the 26 capitals and the Federal District, with data from the National Adolescent Health Survey (2012). The outcome variable was the reported regular physical activity (PA) of ninth graders in Brazilian schools. Exposure variables included characteristics of the natural environment, socioeconomic and educational indicators, urban infrastructure, urban violence, and sociocultural factors retrieved from several secondary sources of Brazilian databases. We adopted multiple linear regression to verify the association between PA and exposure variables. The percentage of active adolescents was 33.0% (95%CI: 32.1; 33.9). In the final model, higher PA was associated with lower temperature, higher Primary Education Development Index, the higher percentage of ramps for wheelchair users, and a higher percentage of leisure-time active adults. The data show that climatic and educational factors, the infrastructure, and the social environment of the capitals can contribute to Brazilian adolescents complying with the recommended weekly PA levels.*

Key words *Physical activity, Adolescent, Infrastructure, Social environment, Temperature*

Resumo *Este estudo teve como objetivo analisar a associação entre atividade física em adolescentes e ambientes construído e social das capitais brasileiras. Trata-se de um estudo ecológico cujas unidades de análise foram as 26 capitais e o Distrito Federal, com dados da Pesquisa Nacional de Saúde do Adolescentes (2012). A variável de desfecho foi a prática regular de atividade física (AF) relatada pelos escolares do 9º ano de escolas brasileiras. As variáveis de exposição incluíram características do ambiente natural, indicadores socioeconômicos e educacionais, de infraestrutura, violência urbana e fatores socioculturais, obtidas de diferentes bases de dados de fontes secundárias brasileiras. Adotou-se a regressão linear múltipla para verificar a associação entre AF e variáveis de exposição. O percentual de adolescentes ativos foi de 33,0% (IC95%: 32,1; 33,9). No modelo final, foram associados à maior prática de AF: menor temperatura, maior Índice de Desenvolvimento da Educação Básica, maior percentual de rampa para cadeirante e maior percentual de adultos ativos no lazer. Os dados mostram que fatores climáticos e educacionais, a infraestrutura e o ambiente social das capitais podem contribuir para que os adolescentes brasileiros cumpram os níveis semanais recomendados de AF.*

Palavras-chave *Atividade física, Adolescente, Infraestrutura, Ambiente social, Temperatura*

[1] Instituto de Saúde Coletiva, Universidade Federal de Mato Grosso. R. Quarenta e Nove 2367, Boa Esperança. 78060-900 Cuiabá MT Brasil. julianailidio_enf@hotmail.com
[2] Observatório de Saúde Urbana de Belo Horizonte, Escola de Medicina, Universidade Federal de Minas Gerais. Belo Horizonte MG Brasil.
[3] Division of Gastroenterology and Liver Diseases, Case Western Reserve University School of Medicine. Cleveland OHIO USA.
[4] Escola de Enfermagem, Universidade Federal de Minas Gerais. Belo Horizonte MG Brasil.

Introduction

Living in cities is a significant demographic shift in recent decades for most of the global population. Estimates reveal that more than half of the world's population lives in urban areas and could reach 70% by 2050. In Latin America, more than 80% of the region's population resides in cities[1].

The growing urbanization process includes a dense and complex intersection of natural, built, and social environments in the cities[2]. In this context, the physical and social environment have been increasingly investigated as determinants of individuals' habits and behaviors, including physical activity[3,4].

Ecological models propose that the planning and implementing more effective actions to face physical inactivity depend on understanding its determinants at several influencing levels[5,6]. This approach involves exploring the urban environment to understand its role in access, conditions, and safety to make physical activity part of everyday life for city dwellers[7]. It includes land use, security, transport, economy, housing, infrastructure and urban design, and availability of leisure facilities[5,7].

Research on this topic, especially adolescents, has increased in recent years, primarily in high-income countries.[5] Studies have identified that increased levels of physical activity among adolescents were influenced by climate[8,9], air pollution[9,10], rainfall[8], socioeconomic level[9,11], traffic violence and crime[12,13], infrastructure and urban design[14-16], afforestation, access to places for regular physical activity[12,17], education[18] and sociocultural support[19,20].

However, it is observed from systematic reviews that evidence is still needed to help understand the relationship between physical activity in adolescents and the natural, built, and social environment, especially in low- and middle-income countries[5,17,18,21,22]. Precisely in Brazil, the scientific production that addresses the topic consists of studies with local samples, the vast majority evaluating the physical activity associated with the perceived environment, with results that are still not consistent[12,15,23-26].

Thus, this study aimed to analyze the association between adolescents' physical activity and the Brazilian capitals' built and social environment. We hypothesized that mild temperatures, flat surface (slope < 30 degrees), better socioeconomic and educational and infrastructure indicators, lower violence rate, and greater sociocultural support for physical activity would be positively associated with the percentage of active adolescents living in urban areas.

Methods

Study design and sample

This ecological study employed data from the National School Health Survey (PeNSE), a nationwide school-based survey carried out in 2012, with representatives of ninth-graders from Brazilian public and private schools, from the North, Northeast, Southeast, South, and Midwest, and the 27 capital cities (26 states and the Federal District),[27] besides different secondary data sources on the natural environment, socioeconomic and educational indicators, infrastructure, violence, and sociocultural factors.

The PeNSE sample consisted of 27 geographic strata corresponding to capital cities and the Federal District. A sample of clusters was selected in two stages for each stratum. First, a sample of schools (primary sampling units) was selected. Subsequently, these schools were visited, and their ninth-grade classes were randomly listed, composing the secondary sampling units. All students from the selected classes, present on data collection, were invited to answer the survey questionnaire[27].

Of the total number of students who regularly attended classes (132,123), in the selected classes, only 110,873 attended classes on the data collection date. However, 1,651 did not wish to participate and 118 did not inform gender or age, being excluded from the database. Thus, the final sample of PENSE, 2012 edition, was composed of 109,104 respondents[27]. For the analyses of this article, 61,145 adolescents residing in the state capitals were evaluated.

All adolescents included in the study signed an informed consent form. The student's information is confidential. The PeNSE, carried in 2012, was approved by the National Research Ethics Commission. A detailed description of the sampling process and other information about PENSE can be obtained in the research report, previously published by the Brazilian Institute of Geography and Statistics[27].

Variables

The outcome variable of this study was the proportion of active adolescents per capital, that is, those who reported practicing 300 minutes or

more of accumulated physical activity per week[28]. The variable was obtained from the PENSE questionnaire (physical activity block) and created from the combination of six questions that consider information on frequency and time spent on physical activity practices in the last seven days prior to the survey. Three different domains were included[27]: 1) commuting to school (in the last seven days, on how many days did you walk or walk to or cycle to school?; when do you go to or from school walking or cycling, how much time do you spend?); 2) physical education at school (in the last seven days, how many days did you have physical education classes at school?; in the last seven days, how much time per day did you practice physical activity or sport during physical education classes at school?); 3) other extracurricular physical activities (in the last seven days, not counting physical education classes at school, how many days did you practice physical activity such as sports, dance, gymnastics, bodybuilding, fights, or other exercises?; how long do these activities (such as sports, dancing, gymnastics, bodybuilding, fights, or other activity) that you do usually last?). To calculate the total accumulated physical activity practice time, the frequency (days) was multiplied by the duration (time of daily practice) of the referred activity in each domain, followed by the sum of the three domains resulting in the total time of practice of physical activity.

Additionally, the variables proportion of male adolescents and mean age per city were retrieved from PeNSE (general information block). The explanatory variables were obtained from several secondary data sources and measured at the city level. These variables were divided into five domains described below, with their respective sources.

Natural environment: Consisting of climatic and geographic variables. The former was collected from the database available on the website of the National Institute of Meteorology[29] website, considering a six-month period from the beginning to the end of the PeNSE 2012 data collection (April 1st, 2012 – September 30, 2012). The following measurements were created: mean maximum temperature, mean minimum temperature, mean compensated temperature (in degrees Celsius (ºC)), number of rainfall days (number), mean total rainfall (mm), and mean relative air humidity (%)[29]. Climate data of the cities of Porto Velho and Campo Grande were not available at the INMET website, and they were obtained from spreadsheets sent by the Institute. Moreover, there were two months of relative air humidity data missing from the city of Vitoria.

Vis-à-vis the geographic variables, the mean slope values of Brazilian capitals were obtained through the geoprocessing software (SRTM-ArcGis Desktop version 10.3.1 and the Spatial Analyst and 3D Analyst extensions), which allows measuring the slope of each geographic area in degrees horizontally (0°-90°), or in percentage, where a slope of 45 degrees is equivalent to 100% slope.

Socioeconomic and educational indicators: Composed of the Municipal Human Development Index (MHDI)[30]; per capita income[31]; Gini coefficient[32], both from the year 2010, and Primary Education Development Index (IDEB)[33]. The IDEB is a national indicator of educational quality that combines information on performance in standardized Portuguese and Mathematics exams (*Prova Brasil* or Primary Education Assessment System (SAEB)), achieved by students at the end of elementary school stages (4th-5th grades – initial year; 8th-9th grades – final year) with data on school performance (approval/pass grade)[33,34]. In this study, the IDEB mean was used for each capital from four measures referring to state schools (initial year + final year) and municipal schools (initial year + final year) of the year 2013. There are only state schools in Brasília. Five capitals did not present one of the four IDEB measurements for 2013, hence data available from the previous year was used. The cities of Maceio, Boa Vista and Rio Branco did not have the final grade IDEB for 2013 (9th grade) for municipal schools; therefore, data for 2011, 2007 and 2005 were used. Sao Paulo and Vitoria, in turn, did not have municipal and state initial-year (5th grade) IDEB for 2013, and the values for 2011 and 2009, respectively, were used. Besides these four indicators are the proportion of illiterates of the year 2010[35] and the mean objective test score in the National High School Exam of the year 2012[36].

Infrastructure: Composed of the percentage of the following characteristics in each capital: households with street identification; street lighting; paving; curb/guide; sidewalk; wheelchair ramp; afforestation; storm drain/mouth; open sewer; garbage accumulated in public places. All variables were obtained by the last Brazilian Institute of Geography and Statistics census[37,38].

Urban violence: The following mortality rates were considered for this domain according to the capital: Specific Mortality Rates (SMR) for homicides for all age groups[39], SMR for homicides in the 15-19 age group[39], and SMR for land trans-

port accidents for all age groups[39], all of the year 2012[39].

Sociocultural support for physical activity: In this domain, we evaluated the percentage of respondents (18 years of age or older) of the National Health Survey (carried out in 2013)[40] on: 1) engaged in the recommended leisure physical activity level (> 150 minutes/week of mild or moderate physical activities, or > 75 minutes/week of vigorous physical activity); 2) engaged in work-related physical activity (walking, heavy cleaning, carrying heavy loads, or another activity that requires intense physical effort) for 150 minutes or more/week; 3) physically active when commuting to their usual activities (work, school), requiring at least 30 minutes a day to commute to/from activities such as walking or cycling; 4) engaged in physical activity for 150 minutes or more while performing household activities (heavy cleaning or activities that require intense physical effort)[28]. The percentage of students with two or more days of physical education school classes was also included in this domain and obtained from PeNSE carried out in 2012[27].

Data analysis

We performed simple and multiple linear regressions to verify the physical activity-associated factors, with estimated regression coefficient and their respective confidence intervals. The explanatory variables were standardized due to their different scales.

All explanatory variables with p-value < 0.20 in the univariate analysis were considered suitable for entering the multiple models, and those with p-value < 0.05 remained in the final model. In the multiple analysis, we adopted the hierarchical entry of variables in blocks: natural environment, socioeconomic and educational indicators, infrastructure, urban violence, and sociocultural support for physical activity. The most distal variables remained as an adjustment for those in the more proximal blocks. The proportion of male adolescents and mean age were included as an adjustment in all models.

We evaluated collinearity separately in each domain, considering Spearman's correlation coefficient (Supplementary Materials, available at: https://doi.org/10.48331/scielodata.AAEDDM). When two variables were collinear, the one with the highest coefficient of determination (R^2) in the univariate analysis was maintained. Therefore, the following were included in the multiple analysis: the mean minimum temperature and relative air humidity (natural environment domain); IDEB and per capita income (socioeconomic and educational indicators domain); households with a ramp for wheelchair users and open sewage (infrastructure domain); SMR for homicides for all age groups (urban violence domain); leisure-time active adults and schoolchildren with two or more days of physical education classes at school (sociocultural support domain for physical activity).

We performed a residual analysis to verify normality, homoscedasticity, and linearity assumptions. Analyses adopted Stata software, version 16 (Stata Corporation, College Station, U.S.). We employed a 5% significance level.

Results

The final sample consisted of 61,145 adolescents (50.84% girls) from 2,219 classes in 1,469 schools. The rate of active adolescents was 33.0% (CI: 32.1-33.9) in the capital cities and the Federal District. The rates of active adolescents were higher in Brasília (39.9%), Campo Grande (38.5%), and Curitiba (38.3%), while Teresina (27.6%), São Luís (27.7%), and Maceió (27.9%) were at the opposite extreme (Figure 1).

Table 1 shows the mean of each context variable for the set of capitals and the Federal District. We observed a mean maximum temperature of 29.68ºC and a minimum of 20.11ºC. The mean MHDI was 0.78, and the mean IDEB was 4.30. We identified a low proportion of households with garbage accumulated in the streets (6.40%), with a ramp for wheelchair users (7.28%), and with open sewage (17.65%). On the other hand, more than 70% of the households had public lighting (96.11%), paving (82.35%), and curbs/guides (71.43%). The mean SMR for homicides in the 15-19 age group was high (91.60/100,000 inhabitants), while the SMR for land transport accidents for all age groups was 19.93/100,000 inhabitants. Approximately 50% of adolescents had two or more days of physical education at school (Table 1).

The variables of the natural environment, socioeconomic and educational indicators, infrastructure, urban violence, and sociocultural support for physical activity were significantly associated with accumulated physical activity (Table 2). The mean minimum temperature, IDEB, households with a wheelchair ramp, and leisure-time active adults maintained statistical

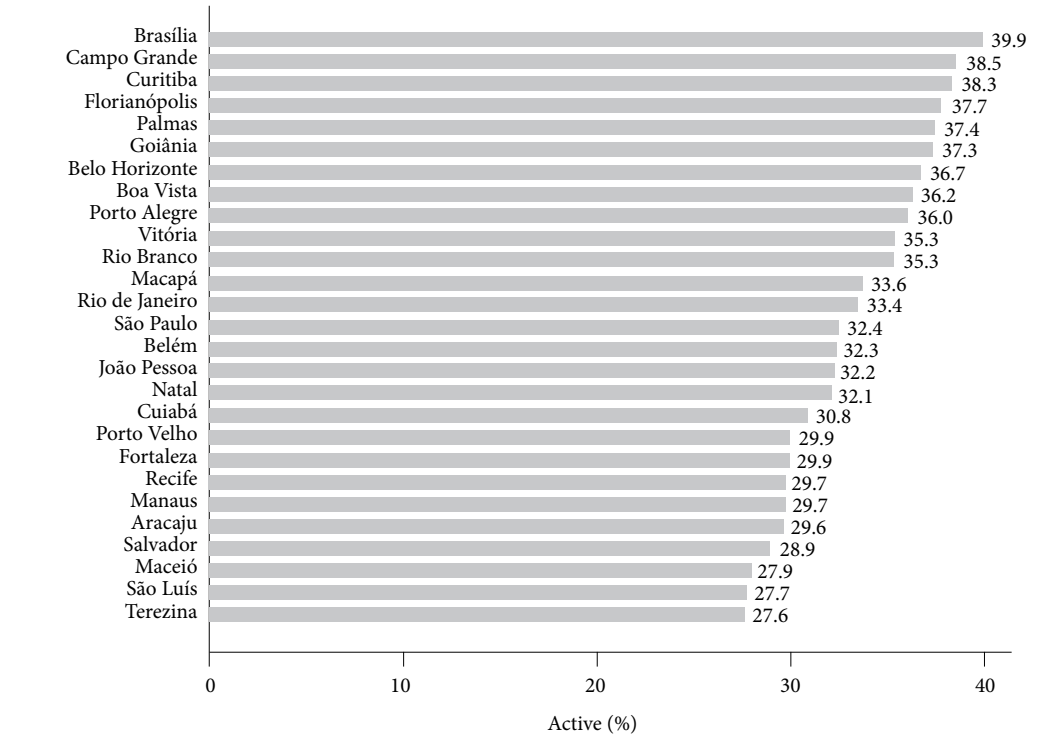

Figure 1. Proportion of accumulated physical activity in adolescents according to the 27 Brazilian capitals. National Adolescent School-based Health Survey, Brazil, 2012.

Source: Authors.

significance in the multiple analysis. The analysis indicated that increasing the minimum temperature by one standard deviation reduces the percentage of active adolescents (Model 1). The increase of one standard deviation of IDEB (Model 2), percentage of ramp for wheelchair users (Model 3), and percentage of leisure active adults (Model 4) increase the percentage of active adolescents (Table 3).

Discussion

This is the first Brazilian nationally representative study to evaluate the association of urban contextual variables and physical activity among adolescents in Brazilian capitals. The main findings of this study pointed to an association between lower average temperature, high educational quality, better urban infrastructure, and high percentage of leisure-time active adults and physical activity among adolescents.

In this study, a negative association was found between the mean minimum temperature and the percentage of active adolescents. However, this result differs from previous studies in European countries, which observed that higher temperatures were associated with higher levels of physical activity[22]. Recently, Zheng et al.[22] conducted the first systematic review and meta-analysis on the associations between climatic conditions and physical activity. They observed a positive association between temperature and physical activity and identified that children and adolescents (aged 3-19 years, from Australia and European, North American, and Asian countries) were more active in favorable climatic conditions, such as temperature around 20°C and less rain. A study using the ecological approach evidenced that the proportion of active English adolescents and adults among those who lived in pleasant places (mild climate and low pollution) was higher than those who lived in hostile environments (exposed to cold weather, pollution, and living near factories)[9]. While this study objectively evaluated the measured temperature, research in Latin American countries, especially Brazil, has used only the perception of barriers,

Table 1. Description of variables in the natural environment, socioeconomic and education indicators, infrastructure, urban violence and sociocultural support to practice physical activity. Brazil, 2010-2013.

Variables	Mean	Std. dev.	Min., max.
Natural environment domain			
Mean maximum temperature (°C)	29.68	3.63	21.61, 35.48
Mean minimum temperature (°C)	20.11	3.54	11.82, 24.79
Mean compensated temperature (°C)	24.25	3.43	15.63, 28.09
Number of rainy days (amount)	67.48	31.67	19.00, 132.00
Mean total rainfall (mm)	109.78	59.41	27.48, 258.38
Mean relative air humidity (%)	73.94	9.57	52.95, 85.06
Maximum slope (%)	52.56	27.60	16.90, 100.00
Mean slope (%)	5.58	3.33	1.47, 14.36
Socioeconomic and education indicators domain			
MHDI	0.78	0.04	0.72, 0.85
Per capita income (BRL/1000)	0.94	0.30	0.63, 1.57
IDEB	4.30	0.58	3.15, 5.40
Gini index	0.61	0.03	0.55, 0.69
Average of the objective test score on the ENEM	527.50	25.87	483.30, 568.52
Illiterate rate (%)	4.94	2.45	1.90, 11.30
Infrastructure domain			
Households with street identification (%)	66.69	20.63	21.00, 94.10
Households with public lighting (%)	96.11	3.61	81.70, 99.60
Households with pavement (%)	82.35	13.77	49.70, 99.20
Households with curb (%)	71.43	21.48	16.00, 97.50
Households with sidewalk (%)	67.45	19.40	18.20, 94.00
Households with wheelchair ramp (%)	7.28	6.81	0.80, 24.80
Households with trees (%)	58.00	22.69	13.90, 96.40
Households with storm drain (%)	46.05	22.70	7.00, 90.00
Households with open air sewage (%)	17.65	18.89	0.50, 71.80
Households with garbage piled on streets (%)	6.40	3.44	0.80, 15.20
Urban violence domain			
Mortality rate from homicide for all age groups (per 100,000)	41.33	16.78	14.30, 79.80
Mortality rate from homicide for 15-19-year-old group (per 100,000)	91.60	57.42	28.10, 223.60
Mortality rate from land transportation accidents for all age groups (per 100,000)	19.93	8.01	9.20, 44.30
Sociocultural support domain to practice physical activity			
Active adults in leisure (%)	26.94	4.43	19.10, 35.70
Active adults at work (%)	10.33	2.24	7.30, 15.50
Active adults travelling (%)	28.40	6.23	18.10, 37.90
Active adults in domestic chores (%)	12.25	3.05	7.70, 20.30
Students who had two or more days of physical education (%)	48.97	21.13	14.30, 80.50

MHDI: Municipal Human Development Index; IDEB: Basic Education Development Index; ENEM: National High School Test.

Source: Authors.

also showing that the unfavorable climate was associated with a higher prevalence of physical activity in adolescents[41,42].

The possible explanations for our result fall into two aspects. The first refers to a specific behavior in which too much heat or cold can directly reduce physical activity, primarily in open environments[6,43]. It is noteworthy that increasing temperature in Brazilian capitals reduces thermal comfort[44] and, consequently, the proportion of active adolescents. Second, land-use policies can affect the availability of open spaces, and transport policies can affect air quality, causing considerable climate change (e.g., temperature), which

Table 2. Univariate association between accumulated physical activity in adolescents and variables in the natural environment, socioeconomic and education indicators, infrastructure, urban violence and sociocultural support to practice physical activity. Brazil, 2010-2013.

Variables	β	95%CI	p-value	R^2
Natural environment domain				
Mean maximum temperature (°C)	-1.46	-2.89, -0.03	0.046* [a]	0.15
Mean minimum temperature (°C)	**-2.31**	**-3.53, -1.08**	**0.001***	**0.37**
Mean compensated temperature (°C)	-2.14	-3.42, -0.86	0.002* [a]	0.32
Number of rainy days (amount)	-1.24	-2.70, 0.23	0.095* [a]	0.11
Mean total rainfall (mm)	-0.50	-2.03, 1.04	0.512	0.02
Mean relative air humidity (%)	**-1.68**	**-3.06, -0.29**	**0.020***	**0.20**
Maximum slope (%)	1.29	-0.16, 2.75	0.079* [a]	0.12
Mean slope (%)	0.76	-0.76, 2.28	0.311	0.04
Socioeconomic and education indicators domain				
MHDI	2.36	1.15, 3.57	< 0.001* [b]	0.39
Per capita income (BRL/1000)	**2.38**	**1.17, 3.58**	**< 0.001***	**0.40**
IDEB	**2.58**	**1.45, 3.71**	**< 0.001***	**0.47**
Gini index	-2.05	-3.35, -0.74	< 0.001* [b]	0.29
Average of the objective test score on the ENEM	1.14	-0.34, 2.62	0.125* [b]	0.09
Illiterate rate (%)	-2.08	-3.38, -0.79	0.003* [b]	0.31
Infrastructure domain				
Households with street identification (%)	2.16	0.89, 3.43	0.002* [c]	0.32
Households with public lighting (%)	0.94	-0.56, 2.44	0.209	0.06
Households with pavement (%)	1.07	-0.42, 2.55	0.152* [c]	0.08
Households with curb (%)	0.64	-0.89, 2.17	0.399	0.03
Households with sidewalk (%)	-0.09	-1.64, 1.46	0.906	0.01
Households with wheelchair ramp (%)	**2.24**	**0.99, 3.49**	**0.001***	**0.35**
Households with trees (%)	1.06	-0.43, 2.54	0.157* [c]	0.08
Households with storm drain (%)	1.76	0.39, 3.13	0.014* [c]	0.22
Households with open air sewage (%)	**-2.24**	**-3.49, -0.99**	**0.001***	**0.35**
Households with garbage piled on streets (%)	-1.68	-3.07, -0.30	0.019* [c]	0.29
Urban violence domain				
Mortality rate from homicide for all age groups (per 100,000)	**-2.29**	**-3.52, -1.06**	**0.001***	**0.37**
Mortality rate from homicide for 15-19-year-old group (per 100,000)	-1.56	-2.98, -0.15	0.031* [d]	0.17
Mortality rate from land transportation accidents for all age groups (per 100,000)	0.36	-1.19, 1.90	0.637	0.01
Sociocultural support domain to practice physical activity				
Active adults in leisure (%)	**2.57**	**1.44, 3.70**	**< 0.001***	**0.47**
Active adults at work (%)	1.31	-0.15, 2.76	0.076* [e]	0.12
Active adults travelling (%)	-0.28	-1.83, 1.26	0.709	0.01
Active adults in domestic chores (%)	0.72	-0.80, 2.24	0.338	0.04
Students who had two or more days of physical education (%)	**2.41**	**1.22, 3.60**	**< 0.001***	**0.41**

MHDI: Municipal Human Development Index; IDEB: Basic Education Development Index; ENEM: National High School Test. R^2: determination coefficient. In bold, the variables that were considered for multiple linear regression. *P-value < 0.20. [a] Collinear variable with "Mean minimum temperature" not used in posterior analyses. [b] Collinear variable with "IDEB" not used in posterior analyses. [c] Collinear variable with "Percentage of households with open air sewage" not used in posterior analyses. [d] Collinear variable with "Mortality rate from homicide for all age groups" not used in posterior analyses. [e] Collinear variable with "Percentage of active adults in leisure" not used in posterior analyses.

Source: Authors.

could restrict physical activity and impact health[7]. Thus, public policies investing in the increase of green areas and including access to sports facilities in open spaces[8], air protection and improvement, and the planning of transport infrastructure could promote the health of urban dwellers[7].

Table 3. Hierarchical model of association between accumulated physical activity in adolescents and variables in the natural environment, socioeconomic and education indicators, infrastructure, urban violence and sociocultural support to practice physical activity. Brazil, 2010-2013.

Variables	Model 1		Model 2		Model 3		Model 4	
	β	95%CI	β	95%CI	β	95%CI	β	95%CI
Block 1 (natural environment) [a]								
Mean minimum temperature (°C)	**-1.63**	**-3.12, -0.14***	-1.13	-2.57, 0.30	0.09	-1.57, 1.75	-0.14	-1.52, 1.24
Block 2 (socioeconomic and education indicators) [b]								
IDEB			**1.76**	**0.21, 3.31***	2.17	0.73, 3.61	1.60	0.35, 2.85
Block 3 (infrastructure) [c]								
Households with wheelchair ramp (%)					**1.73**	**0.27, 3.20***	1.07	-0.21, 2.36
Block 4 (sociocultural support to practice physical activity) [d]								
Active adults in leisure (%)							**1.54**	**0.56, 2.51***
AIC	139.52		135.44		130.62		120.96	
R^2	0.37		0.47		0.57		0.71	

IDEB: Basic Education Development Index; AIC: Akaike information criteria; R^2: determination coefficient. All models were adjusted per sex and age. [a] Block 1. [b] Controlled by block 1. [c] Controlled by blocks 1 and 2. [d] Controlled by blocks 1, 2 and 3. *P-value < 0.05.

Source: Authors.

IDEB is an educational quality indicator that allows, for example, identifying schools with low incomes and increasing the transfer of financial resources to improve this result[34]. To the best of our knowledge, this is the first time this indicator has been used to assess the association between the quality of education and the percentage of active adolescents using population-based data. In this study, IDEB was positively associated with the percentage of active adolescents, indicating that improving educational quality can increase the proportion of active students, precluding noncommunicable chronic diseases such as hypertension, diabetes, and other diseases[28].

This result may be partially justified because capitals with better education can promote awareness activities about healthy habits and behaviors[45]. Guidance on the physical activity benefits is vital for adopting a more active lifestyle[28]. The educational environment and health education through the dissemination of knowledge and skills development allow students to incorporate healthy behaviors and enable them to participate as subjects of their health process[45]. Additionally, high IDEB values may be related to better conditions in the school environment, which range from pedagogical resources to physical infrastructure, such as the presence of sports equipment[46]. In the latter case, schools that have more and/or better physical activity facilities can encourage the practice of physical activity inside and outside the school and, therefore, students may be more likely to be active enough[47,48]. These findings suggest that the school environment also plays an important role in the health of students. Therefore, public policies aimed at education must guarantee, among other aspects, material resources and infrastructure in adequate conditions for the practice of physical activity[46,48].

Furthermore, we found a positive and significant correlation between IDEB and per capita income and MHDI, a proxy for the city's socioeconomic level. It is essential to consider that the socioeconomic inequality level of a place can contribute to the unequal distribution of urban infrastructure[5]. Lower-income peripheral areas tend to have worse quality of features of the physical activity-related built environment, influencing the probability of being active[11]. For example, American teenagers from low-income neighborhoods were less likely to be active in commuting due to their low ability to walk in the neighborhood[49]. Furthermore, Brazilian adolescents residing in neighborhoods with better per capita household income were more likely to be active in leisure time[15].

Among the indicators of the infrastructure domain, we observed a positive association between the percentage of households with a ramp for wheelchair users and physical activity. The ramp was defined as "a lowering of the sidewalk or curb/guide, usually near corners, specifically intended to give access to people using wheelchairs"[38]. It is noteworthy that the installation of

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ramps must follow specific criteria established by the Brazilian Association of Technical Standards[50], such as slope not exceeding 8.33%, minimum width of 1.20 m, and non-slip floor. A city with a higher percentage of wheelchair ramps probably also has better quality sidewalks (fewer holes and more suitable walking floors) and a better infrastructure in general, which would facilitate leisure-time physical activity for children and adolescents, such as walking, cycling, and skateboarding[51].

Studies investigating the association between city infrastructure and physical activity levels among adolescents have increased in recent decades. In these works, researchers have shown that other urban design attributes can influence the likelihood of more active adolescents, such as the availability of sidewalks[14], location and material of sidewalks[16], public lighting, paved streets[15], bicycle lanes[15,17], and intersection density (street connectivity)[16,52]. These results strengthen the findings of this study, indicating that interventions in the urban infrastructure can influence the physical activity levels in adolescents.

Regarding physical activity's sociocultural support, we observed that a higher percentage of leisure-time active adults was associated with regular physical activity in adolescents, which is consistent with results obtained by other studies, showing that having active adults at home contributes to an increase in physical activity, especially among boys[19,20]. In general, parents and relatives can play an essential role in increasing physical activity levels,[53] so that the higher the percentage of adults engaged in physical activity, the greater the incentive for adolescents to engage in physical activity[20]. This association can be explained by the social learning theory, which considers that people learn by observing others. In the practice of physical activity, it can be expressed through the modeling of interests and skills and in the reinforcement of behaviors[54].

Some scholars argue that social support has been considered an essential factor for adopting a more active lifestyle[23], which can occur through emotional, financial, material[55], organizational, community, or political support[18]. Adolescents with more supportive parents, siblings, and friends tend to participate in a higher physical activity level[18,55]. Moreover, we could consider that cities with more active adults have more physical activity structure, such as public spaces for leisure sports[56,57]. While not evaluated in this study, the research results above reinforce the importance of promoting public policies to foster physical activity in adolescents with a socio-ecological approach.

Regarding the urban violence domain, only homicide rates were associated with the percentage of active adolescents in the crude analysis, which was not maintained in the adjusted analysis. As far as we know, in Brazil, only one study analyzed the association between physical inactivity and the homicide rate among adolescents living in 122 municipalities with over 100,000 inhabitants. It was part of the Study of Cardiovascular Risk Factors in Adolescents, in which researchers found no significant association[58]. Previously published studies have investigated the relationship between physical activity and urban violence from adolescents' perspectives. However, inconsistent results persist. While Mendonça et al.[12] showed that adolescents from João Pessoa who perceived that the neighborhood environment was not violent were more likely to report active commuting, other national studies have not found an association between urban violence and adolescent physical activity[23-25].

Significant associations were found between perceived level of safety in the neighborhood (walking/cycling infrastructure, traffic risks, and crime safety) and leisurely walking in Poland and the Czech Republic, which was stronger in girls and transport walking.[13] These studies reveal the difficulty of comparing studies due to the different methodological approaches to assess urban violence, and few works specifically evaluated homicide vis-à-vis physical activity in adolescents.

This study has limitations inherent to its ecological design: variables that would contribute to physical activity among adolescents, such as the availability of public and private leisure facilities (e.g., gyms, courts, soccer fields, and parks), were not included. Additionally, there may be heterogeneous attributes within cities, and we were unable to assess the neighborhood of each adolescent. Although it is an index that only considers public schools, IDEB is representative of the outcome studied since 75% of the PeNSE sample (2012) in the capitals derives from public schools.

Furthermore, the same variables remained associated when only the percentage of active adolescents from public schools were considered, and the latter model had lower explanatory power than the one that evaluates students from public and private schools. Nevertheless, the major strength of this study was that it had a nationally representative sample of adolescents evaluating the association between several environmental

factors (natural, constructed, and social) and regular physical activity, allowing the generalization of the results.

Conclusions

The study observed that climatic and educational factors, infrastructure, and social context could increase the percentage of active Brazilian adolescents. The environment of cities impacts health, and there is a need for healthier and more sustainable cities. Urban planning policies and their interfaces must be multisectoral. They must integrate and prioritize transport, land use, the economy, housing, and infrastructure planning with urban design, which will protect citizens from traffic, environmental pollution, noise, crime, and violence and promote active lifestyles such as safe walking, cycling, and access to parks.

Collaborations

JI Silva participated in the design of the study and its conception; was responsible for writing the article, performed the statistical analysis, ensured the accuracy and precision of the data and approved the final version of the paper. LA Condessa participated in the design of the work, setting up the database, performed the statistical analysis, ensured the accuracy and precision of the data, helped to draft and approved the final version of the paper. DAS Costa participated in the setting up the database, performed the statistical analysis, ensured the accuracy and precision of the data and approved the final version of the paper. FA Célio participated in the setting up the database, performed the statistical analysis, ensured the accuracy and precision of the data and approved the final version of the paper. DC Malta participated in the design of the field work and ensured the accuracy and precision of the data and approved the final version of the paper. ACS Andrade Participated in the design of the work, performed the statistical analysis, ensured the accuracy and precision of the data, critical review of all versions of the article and approved the final version of the paper. WT Caiaffa Participated in the design and construction of the field work, ensured its accuracy and integrity, critical review of all versions of the article and approved the final version.

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