

## Mediation role of residential density on the association between perceived environmental factors and active commuting to school in Brazilian adolescents

O papel de mediação da densidade residencial na associação entre fatores ambientais percebidos e deslocamento ativo à escola em adolescentes brasileiros

El papel mediador de la densidad poblacional en la asociación entre los factores ambientales percibidos y el desplazamiento activo a la escuela en adolescentes brasileños

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doi: 10.1590/0102-311X00067620

### Abstract

The objective of this study was to verify whether residential density and connectivity between streets are mediators on the association between perceived environmental factors and active commuting to school (ACS) in Brazilian adolescents. This is a cross-sectional study with a random sample of 1,130 adolescents (52.7% girls) aged between 14 to 20 years, from Porto Alegre, Rio Grande do Sul State, Brazil. Adolescents' self-reported their usual mode of commuting to and from school using a questionnaire and the perceived environmental attributes by Neighborhood Environment Walkability Scale for Youth (NEWS-Y). Residential density and connectivity between streets were measured by geographic information systems (GIS), within 1km road network buffers around the participant's residential address. Regression models were fitted according to mediation analyses procedures. The results showed that residential density is a mediator on the association between ACS and perceived environmental factors, including land-use mix diversity (IE = 0.114; 95%CI: 0.130, 0.311; 32% mediation), neighborhood recreation facilities (IE = 0.064; 95%CI: 0.034, 0.105; 15% mediation), and access to services (IE = 0.045; 95%CI: 0.006, 0.104; 14% mediation). Connectivity between streets did not correlate with ACS, thus it was not tested in the mediation model. In conclusion, residential density is a mediator on the relationship between perceived environmental factors and ACS.

*Built Environment; Transportation; Physical Activity; Students*

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## Introduction

The prevalence of cardiometabolic risk factors, such as obesity, type 2 diabetes, and hypertension have been increasing in children and adolescents over the years <sup>1</sup>. These non-communicable diseases are with low levels of physical activity in this population <sup>2</sup>. Active commuting to and from school (ACS) (i.e., walking or cycling) is a reasonable form of physical activity among children and adolescents, recognized as an opportunity for health promotion <sup>3,4</sup>. Increase in daily physical activity <sup>4,5</sup> and cardiorespiratory fitness <sup>6</sup>, as well as the decrease in metabolic syndrome incidences <sup>7</sup> and waist circumference <sup>8</sup>, are some of the positive health factors associated with ACS. Since most school children must travel to and from school twice a day, this behavior could be integrated into their individual routines. In this sense, previous review studies have identified numerous interventions of ACS promotion and its association with several health indicators in children and adolescents <sup>9,10,11</sup>.

Adolescents' mode of commuting is influenced by personal, social, and environmental factors <sup>12,13</sup>. For instance, Mandic et al. <sup>13</sup> showed that shorter distance to school, younger age, fewer vehicles, opportunity to chat with friends, nice scenery, and parental perceptions of safety when active commuting to school were positively associated with ACS in adolescents. Studies have also shown that walkability is a physical environmental factor that influences physical activity and active commuting in youths <sup>14,15,16</sup>. Regarding the environmental perceived factors, results indicate that traffic and crime safety <sup>17</sup>, land-use mix diversity <sup>18</sup>, shorter distance to school, and access to destination <sup>19</sup> were associated with ACS in adolescents. Thus, we emphasize that safe neighborhoods with easy access and nice aesthetics could improve adolescent's perception, increasing ACS <sup>20,21</sup>. In fact, good available environments is not enough, people need to perceive them as adequate for use.

Recently, studies have investigated how much the physical environment influenced ACS. A previous systematic review pointed out that higher objective accessibility, new infrastructure for walking and cycling, and public transportation were associated with increased ACS <sup>21</sup>. However, all studies included in this review were conducted in high-income economies (North America, Europe, Australia, Asia, and New Zealand). Thus, it is important to emphasize that environmental characteristics associated with physical activity in high-income countries are different from low- and middle-income countries (LMIC) <sup>22</sup>. Besides, few research is available regarding the characteristics of the environment and physical activity of young people in LMIC <sup>22</sup>, emphasizing the need for more research in Latin American countries, specifically in Brazil, where the occurrence of children and adolescents who passively commute to school varies between 43.3% and 52% <sup>23,24</sup>.

Considering the mentioned aspects, we emphasize that exploratory analyses about the relationship between environmental factors and ACS are important to create effective policies for physical activity promotion in regions where evidence about these aspects is still unavailable, especially in developing countries. Likewise, studies investigating the association between ACS with environmental variables in Brazilian youth are scarce. Thus, our study intends to add information to understand whether built environmental variables (objectively measured) influence the relationship between environment perception factors and ACS. Therefore, this study aimed to verify whether residential density and connectivity between streets are mediators on the association between perceived environmental factors and ACS in Brazilian adolescents.

## Methods

### Study design

A cross-sectional study with a quantitative approach was conducted in Porto Alegre, Rio Grande do Sul State, Brazil. This study is part of a wider project entitled *Environmental Factors, Physical Activity and Health*. Porto Alegre has approximately 1.4 million inhabitants (year 2010), a demographic density of 2,837.53 inhabitants/km<sup>2</sup> and a territorial area of 496,681km<sup>2</sup> (Brazilian Institute of Geography and Statistics. <https://cidades.ibge.gov.br/brasil/rs/porto-alegre/panorama>, accessed on 08/Sep/2019). This city is one of the most forested capitals in Brazil; it has approximately 630 squares, eight public parks, and three conservation units, according to data from the Porto Alegre Environ-

ment, Urbanism and Sustainability Department ([http://www2.portoalegre.rs.gov.br/smam/default.php?p\\_secao=297](http://www2.portoalegre.rs.gov.br/smam/default.php?p_secao=297), accessed on 09/May/2021). The population of the study was approximately 34,645 high school students from 71 public schools (Brazilian National Institute for Educational Studies and Research. <http://portal.inep.gov.br/basica-censo-escolarmatricula>, accessed on 08/Sep/2019). They were allocated in the following regions: 15,897 center, 8,057 north, 6,423 south, and 4,268 east.

The following criteria were considered to calculate the sample size: (a) estimated population of 34,645 students (N); (b) proportion of 50% (p); (c) complementary percentage of 100-P (q); (d) confidence level of 1.96 standard deviations (S); and (e) acceptable sampling error of 3% (e). After adopting these criteria and the formula presented below, it was estimated that 1,035 students should be evaluated. However, to avoid probable dropouts in the sample, an increase of 5% was assumed, resulting in 1,086 school-aged adolescents. The formula  $[n = S2.p.q.N/e2(N-1)+(S2.p.q)]$  was used to achieve a sample that represented the study population. This estimate was performed using the formula to have a representative sample of the population.

The software G\*power version 3.1 (<http://www.psych.uni-duesseldorf.de/abteilungen/aap/gpower3>) was used to estimate the sample size necessary for association analysis. Linear regression models were used with test power  $(1-\beta) = 0.85$ , significance level of  $\alpha = 0.05$ , and effect size of 0.02. The considered number of predictors was 13 and the minimum sample size was established as 1,003.

Sample selection considered the proportion of adolescents enrolled in the schools per region. Thus, the sample was composed of 263 adolescents from four public schools in the north region (23.26%); 518 adolescents from seven public schools in the central region (45.88%); 140 adolescents from two public schools in the east region (12.32%); and 209 adolescents from three public schools in the south region (18.54%).

The sample selection was done by a procedure of multiple phases<sup>25</sup>. Initially, the schools were selected according to each region. A number was assigned for each school and all numbers were placed in a box, mixed, and randomly reelected one by one. In the schools, the high school classes were selected randomly. Data was collected in one class from each year: first, second, and third.

The students from the selected classes were invited to participate in the study and the inclusion criteria were (a) belonging to the first, second, or third year of high school; (b) signing the assent document manifesting will to participate; and (c) handing in the informed consent document signed by a parent or guardian. Also, according to Sawyer et al.<sup>26</sup>, a definition of 10-24 years corresponds more closely to adolescent growth and popular understandings of this life phase; thus, we used the term adolescents even when some students were over 18 years of age.

Data collection was performed during an 8-month period in 2017. First, the researchers provided the required information to the selected schools, explaining the aims of the study and, if the managers agreed to participate, they were asked to sign an acceptance term. Then, data collection was scheduled. Adolescents took, on average, 30 minutes to fill out the questionnaire, which was answered during a regular class. The study was approved by the Ethics Committee of Research with Human Beings of the Federal University of Rio Grande do Sul (n. 1,338.597).

## **Measurement procedures**

### **• Mode of commuting to and from school**

Adolescents self-reported their usual mode of commuting using a questionnaire while supervised by a researcher (ratio 2 researchers per 30 students). Consequently, the question "How do you usually get to and from school?" was used. Response choices were (1) on foot, (2) by bicycle, (3) by bus, (4) by car and (5) other. Question about mode of commuting to and from school has been proposed as one of the most appropriate measurements for asking about mode of commuting to school in this population<sup>27</sup>. Active commuters were students that commuted to and from school on foot or cycling, while passive commuters were those who commuted by bus or by car. The students who answered "other" were individually categorized and defined as active or passive commuters according to the transportation that they used.

- **Perceived environmental factors**

To measure self-reported environment perception factors, the instrument *Neighborhood Environmental Walkability Scale for Young* (NEWS-Y) <sup>28</sup> was used, which was previously validated in Brazil for this population <sup>29</sup>. This questionnaire evaluates environment perception factors that may influence adolescents' total physical activity <sup>28</sup>. Questions were developed according to the dimensions (land-use mix diversity, neighborhood recreation facilities, access to services, street connectivity, places for walking, neighborhood aesthetics, neighborhood safety, and crime safety) proposed by the NEWS-Y.

Land-use mix diversity and neighborhood recreation facilities refer to distance perception from home to a variety of destinations, such as shops and school, as well as perceived distance from the student's house, on foot, to places for physical activity practice, such as walking/running tracks, or a large public park. The possible answers were 1-5 minutes, 6-10, 11-20, 21-30, more than 30 minutes, and don't know/there isn't. All items were reverse coded and employed mean values. Questions from the dimensions access to services, street connectivity, places for walking, neighborhood aesthetics, neighborhood and crime safety were measured using 4-point Likert scale (strongly disagree, partially disagree, partially agree, strongly agree). All dimensions were calculated following the NEWS-Y scoring guidelines <sup>30</sup> and the mean value was considered for each dimension. More information about the questions can be found in Lima et al. <sup>29</sup> and Rosenberg et al. <sup>28</sup>, and on the James F. Sallis' website <sup>30</sup>.

- **GIS-measured environmental factors**

Adolescents' addresses, reported in the questionnaire, were geocoded in the geographic information system (GIS) with the ArcMap 10.3.1 software (<https://www.esri.com>). This software was used for the analyses with the shape file of the streets, parks, and squares provided by the Porto Alegre Environment, Urbanism and Sustainability Department. A 1km road network buffer was defined around the participant's residential address to estimate accessible neighborhood features <sup>31</sup>.

The following variables were used: residential density and connectivity between streets. Residential density was calculated using the number of residential units in the area within each buffer. Connectivity between streets was assessed by the number of intersections between the streets in the buffer. These variables were transformed to standardized values (Z-scores).

- **Socioeconomic status**

Socioeconomic status was assessed through a questionnaire, which included the number of owned items at the adolescents' residences and the level of schooling of the parent or guardian, according to the criteria established by the Brazilian Association of Research Companies (<http://www.abep.org/criterio-brasil>, accessed on 08/Sep/2019). Then, students answered questions about the existence and quantity of items in their home, such as car, washing machine, bathroom, among others. In addition, information was given on the origin of the house water (well or spring, general distribution register, or other means), and the street condition of his/her home (asphalted/paved or earth/gravel). For each answer, a score was attributed and the sum of the points identified each student's economic class. Then, subjects were classified into the following economic classes: A1, A2, B1, B2, C1, C2, D, E. For the analyses, the classes were grouped as high (A1+A2), middle (B1+B2), and low (C1+C2+D+E).

### **Statistical analysis**

Descriptive data stratified by usual mode of commuting to and from school were calculated as absolute and relative values for sex, age, and socioeconomic status. Means and standard deviations (SD) were calculated for each GIS-measured objective (residential density and connectivity between street) and perceived environmental factors. These data were presented stratified by active and passive commuters. Differences between ways of commuting to school were determined through chi-square test for dichotomous variables and independent t-test for continuous variables.

The internal consistency from the variables of the NEWS-Y dimensions was verified with Cronbach's alpha (0.89), which indicated 0.89 as an acceptable reliability. Values for each dimension were

land-use mix diversity (0.88), neighborhood recreation facilities (0.84), access to services (0.36), street connectivity (0.36), places for walking (0.30), neighborhood aesthetics (0.71), neighborhood safety (0.10), and crime safety (0.85).

Spearman correlation was used to determine association between GIS-measured objective and perceived environmental factors and ACS. Residential density and connectivity between streets (mediating variables) should be correlated with the outcome. Perceived environmental factors that presented association with both GIS-measured objective environmental factors and ACS were tested in mediation models.

To examine whether the association between perceived environmental factors and ACS was mediated by residential density and connectivity between streets, linear regression models were fitted using bootstrapped mediation procedures included in the PROCESS macro <sup>32</sup>. For mediation hypotheses tests, a resampling procedure of 10,000 bootstrap samples was used. PROCESS estimates models with binary and continuous variables. Indirect effect was estimated through point estimates and 95% confidence intervals (95%CI). When the confidence interval did not contain zero, the point estimate was considered significant.

The following criteria were used to establish mediation: (1) the independent variable (perceived environmental factors) is significantly related to the mediators (equation a); (2) the mediator is significantly related to the dependent variable (ACS) (equation b); (3) the independent variable (perceived environmental factors) is significantly related to the dependent variable (ACS) (equation c); and (4) the association between the independent and dependent variable is attenuated when the mediator is included in the regression model (equation c'). The proportion mediated was calculated by the following formula:  $1 - (\text{equation } c' / \text{equation } c)$ . Other important criteria are that the value of equation b must be greater than the equation c' and the value of equation c' must be smaller than the equation c.

The analyses were adjusted by sex and socioeconomic status. All analyses were carried out using the SPSS-IBM v.22.0 (<https://www.ibm.com/>), and a value of  $p < 0.05$  was considered statistically significant.

## Results

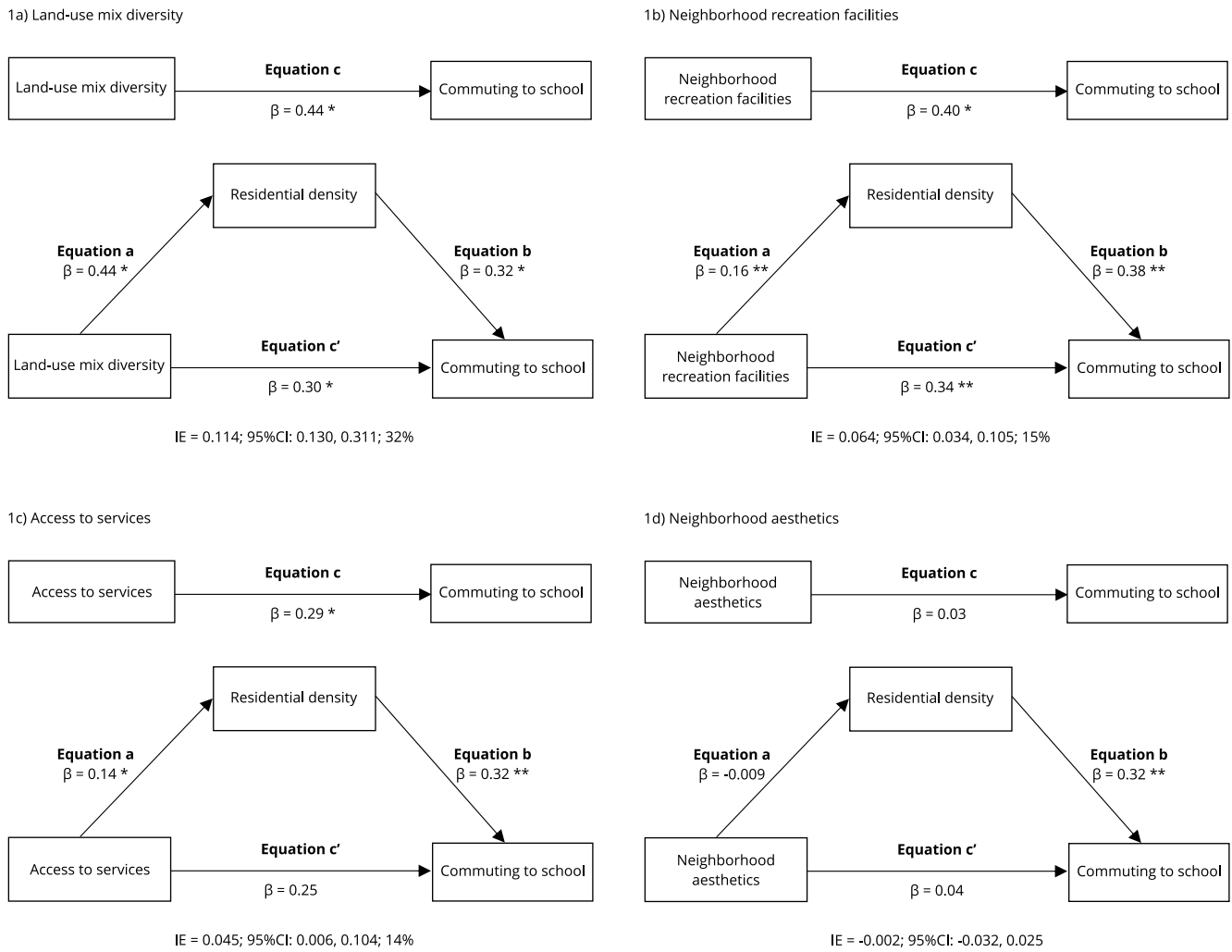
Table 1 presents descriptive characteristics of the sample, stratified by usual mode of commuting to and from school, i.e., active vs. passive commuters. The adolescents (52.7% girls) attended 16 public high schools, their mean age was 16.49 (SD = 1.05) years old. The results indicated significant statistical difference between active and passive commuters by sex ( $\chi^2 = 13.97$ ;  $p < 0.001$ ). Most adolescents were middle class. Residential density and perceived environmental factors, such as land-use mix, neighborhood recreation facilities, access to services, and neighborhood aesthetics were statistically different between active and passive commuters.

Table 2 shows correlations between GIS-measured objective and perceived environmental factors and ACS. It is observed that connectivity between streets was not associated with ACS. Thus, this variable cannot be tested as a mediator. Residential density presented positive correlation with ACS. Some perceived environmental factors (land-use mix diversity, neighborhood recreation facilities, access to services, and neighborhood aesthetics) presented correlation between both residential density and ACS.

The mediator role of residential density in the association between land-use mix diversity, neighborhood recreation facilities, access to services, and neighborhood aesthetics with ACS is in Figure 1. Overall, perceived environmental factors (land-use mix diversity, neighborhood recreation facilities, and access to services) were positively associated with ACS. Mediation analysis, including residential density, revealed that the association between these perceived environmental factors and ACS was mediated by residential density. The roles of this mediation for sex, socioeconomic status, region, and all perceived environmental factors were the following: residential density mediates 32% of land-use mix diversity for ACS (indirect effect [IE] = 0.114; 95%CI: 0.130, 0.311); 15% for neighborhood recreation facilities (IE = 0.064; 95%CI: 0.034, 0.105); and 14% for access to services (IE = 0.045; 95%CI: 0.006, 0.104) parameters. In Figure 1d, residential density did not mediate the relationship between neighborhood aesthetics with ACS.

**Figure 1**

Residential density mediation model of the relationship between land-use mix diversity (1a), neighborhood recreation facilities (1b), access to services (1c), and neighborhood aesthetics (1d) with active commuting to school in adolescents.



95%CI: 95% confidence interval; IE: indirect effect.

Note: the analyses were adjusted for sex, socioeconomic status, region, and all perceived environmental factors.

\*  $p \leq 0.05$ ;

\*\*  $p < 0.001$ .

**Table 1**

Sample's characteristics, descriptive and occurrence analysis according to usual mode of commuting to school in adolescents.

	All n (%)	Active commuters to school [n = 339 (30.2%)] n (%)	Passive commuters to school [n = 784 (69.8%)] n (%)	p-value
Sex				<b>&lt; 0.001</b>
Female	596 (52.7)	150 (44.2)	442 (56.4)	
Male	534 (47.3)	189 (55.8)	342 (43.6)	
Age (years)				-
14-15	208 (18.4)	55 (16.2)	151 (19.2)	
16-17	753 (66.6)	223 (65.8)	522 (66.6)	
18-20	169 (14.9)	57 (16.8)	111 (14.1)	
Socioeconomic status				-
High	202 (18.1)	56 (16.6)	144 (18.7)	
Middle	625 (56.2)	192 (57.0)	431 (55.9)	
Low	286 (25.7)	89 (26.4)	196 (25.4)	
	<b>Mean (SD)</b>	<b>Mean (SD)</b>	<b>Mean (SD)</b>	
Objective (GIS)				
Residential density	7,257.91 (4,106.12)	8,501.54 (4,384.96)	6,689.83 (3,843.68)	<b>&lt; 0.001</b>
Connectivity between streets	186.02 (103.45)	193.18 (100.85)	181.95 (103.25)	0.10
Perceived environmental factors				
Land-use mix diversity	3.56 (0.89)	3.86 (0.90)	3.43 (0.85)	<b>&lt; 0.001</b>
Neighborhood recreation facilities	2.86 (1.05)	3.20 (1.10)	2.72 (0.99)	<b>&lt; 0.001</b>
Access to services	2.96 (0.49)	3.05 (0.46)	2.91 (0.49)	<b>&lt; 0.001</b>
Street connectivity	2.74 (0.68)	2.78 (0.69)	2.72 (0.68)	0.19
Places for walking	2.75 (0.69)	2.77 (0.65)	2.74 (0.71)	0.47
Neighborhood aesthetics	2.55 (0.72)	2.63 (0.73)	2.52 (0.72)	<b>0.01</b>
Neighborhood safety	2.38 (0.46)	2.36 (0.45)	2.39 (0.46)	0.31
Crime safety	2.59 (0.81)	2.60 (0.78)	2.58 (0.82)	0.77

GIS: geographic information systems; SD: standard deviation.

## Discussion

The main findings of this study indicate that residential density (objectively measured) and perceived environmental factors (land-use mix diversity, neighborhood recreation facilities, access to services, and neighborhood aesthetics) are associated with ACS. Results showed that residential density acts as a mediator on the ACS association with land-use mix diversity (32%), neighborhood recreation facilities (15%), and access to services (14%) in adolescents.

In the present study, adolescents that perceived a shorter distance from their home to several places – supermarkets, library, among others (land-use mix diversity) – as well as those who reported better access, nice neighborhood aesthetics, and a short distance from places to practice physical activity – sport clubs, parks, etc. (neighborhood recreation facilities) – actively commuted to school. In agreement with our results, previous studies with adolescents from Belgium, Nigeria, and New Zealand stated that land-use mix diversity<sup>18</sup>, access to services<sup>19</sup>, and nice scenery in the neighborhood<sup>13</sup> were associated with ACS. Duncan et al.<sup>33</sup> showed that a distance of approximately 2km was associated with the best results of physical activity related to active transport (9% to 15% increase on weekdays) in children and adolescents from New Zealand. However, distance to and from school is a very specific variable that differs in each context, even within the same country. For example, in a

**Table 2**

Correlation between active commuting to school, GIS-measured objective, and perceived environmental factors in adolescents.

	Active commuters to school	Residential density	Connectivity between street
Perceived environmental factors			
Land-use mix diversity	<b>0.211 *</b>	<b>0.406 *</b>	<b>0.131 *</b>
Neighborhood recreation facilities	<b>0.198 *</b>	<b>0.285 *</b>	<b>0.149 *</b>
Access to services	<b>0.118 *</b>	<b>0.260 *</b>	<b>0.136 *</b>
Street connectivity	0.035	<b>0.219 *</b>	<b>0.113 *</b>
Places for walking	0.025	<b>0.178 *</b>	<b>0.176 *</b>
Neighborhood aesthetics	<b>0.075 **</b>	<b>0.159 *</b>	0.053
Neighborhood safety	-0.032	<b>-0.139 *</b>	<b>-0.065 **</b>
Crime safety	-0.004	0.006	0.126
Objective (GIS) ***			
Connectivity between street	0.050	<b>0.607 *</b>	-
Residential density	<b>0.186 *</b>	-	-

GIS: geographic information systems.

\*  $p < 0.001$ ;

\*\*  $p < 0.05$ ;

\*\*\* Standardized variables (transformed into Z-score).

study conducted with Spanish adolescents<sup>34</sup>, the limit distance for walking to school was 1,350m, so it is interesting to know what the real distance between home and school is, and what distance is the adolescent able to complete.

Studies developed with Colombian and Chilean children and adolescents indicated that ACS is associated with cultural and geographic factors, however, environmental factors were not considered<sup>35,36</sup>. Studies in low-income countries are scarce, specially concerning the relationship between the specific context of commuting to school with environmental factors in adolescents. In the northeast of Brazil, the aspect “having places they like to go to” was reported by adolescents and positively associated with active commuting<sup>37</sup>. In this sense, a possible explanation for our results is that adolescents are used to walking to different places in the neighborhood, which could be the reason why they actively commute to school.

GIS-measured environmental characteristics associated with ACS have increased in recent years<sup>14,16,38</sup>. Studies in developed countries, such as United States, Spain, and Belgium, found results similar to our study, indicating that residential density was positively associated with active commuting in adolescents<sup>14,15,18,39</sup>. On the other hand, we found that connectivity between streets was not associated with ACS. Queralt & Molina-García<sup>39</sup> showed that street intersection density was positively associated with active commuting in Spanish adolescents. This discrepancy may derive from the different assessment methods that were used for active commuting and the different characteristics of the countries.

Taking these relationships into account, the mediation analysis showed that the residential density variable (objectively measured) attenuated the association between three perceived environmental factors and ACS. That is, higher residential density in the neighborhood influences adolescents' perception of distance to different locations (land-use mix diversity), and places to practice physical activity, as well as better access in the neighborhood for ACS. In this sense, the magnitude of the mediation of residential density could support the hypothesis of the combined environmental measurements (objective and perceived), because higher residential density would not fully influence the relationship of perceived environmental factors (land-use mix diversity, neighborhood recreation



facilities, and access to services) with ACS in adolescents. For example, it is not enough having high residential density and available infrastructure if people do not have a positive perception about the availability of such places, as well as good access in the neighborhood. It should be noted that this mediation role ranged from approximately 14% to 32% for the three investigated perceived environmental factors, which points out to the relevance of these factors for the development of public health strategies. It is important to emphasize that a systematic review indicated that studies providing combined information between perceived and objective environmental factors were unavailable in Brazil, involving adolescents <sup>40</sup>.

Our findings could be relevant for professionals and stakeholders of the public health area. We emphasize that public and health managers, as well as transport agents and urban planning, can develop strategies to promote active commuting in the Brazilian population. Characteristics of urban design such as high-density residential locations, perception of proximity, and easy access to services can encourage students to actively commute to school and, consequently, increase their physical activity levels. Therefore, developing strategies to promote more active cities with built environment resources – as well as other structures, such as walking and running trails and bicycle paths – can have positive impacts on the health of the entire population.

Some limitations of our study should be mentioned. The transversal design of the study does not allow the determination of cause and effect. Also, we did not consider the period that the adolescents lived in that address or neighborhood, which could influence their perceptions. Moreover, the question about mode of commuting was not formally validated, although it has been proposed as one of the most appropriate measurements for determining mode of commuting to school in this population. Finally, larger buffers size was not used and adolescents' ACS time was not determined. Future proposals should include more objective measurements of this behavior <sup>41</sup>. The strengths of the present study include a large sample of Brazilian adolescents and the use of environmental variables measured objectively and subjectively to understand how much this reflects in ACS. Finally, as far as we know, this is the first study using mediation analysis to understand the role of residential density in the association of perceived environment factors with ACS of Brazilian adolescents. Future studies should try to look for causal inferences and remember that understanding the impact of improvements in the infrastructure of built environment, and resources and incentives in the neighborhood or school can positively influence parents and adolescents' perception of the environment, thus increasing the prevalence of ACS. Another important issue is to know the reasons that lead adolescents to actively commute to school. Addressing environmental, social, individual, and political factors can also help elucidate these relationships.

In conclusion, residential density is a mediator on the relationship between perceived environmental factors and ACS in Brazilian adolescents. The connectivity between streets did not correlate with ACS, so it was not tested in the mediation model. Our findings also emphasize that self-reported environmental data, such as land-use mix diversity, neighborhood recreation facilities, and access to services seem to be important factors for ACS in Brazilian adolescents, considering residential density.

## Contributors

A. F. Dias is responsible for all aspects of the article, ensuring the accuracy and integrity of any part of the article. A. R. Gaya and E. Villa-González contributed to the article writing and critically reviewed the intellectual content. C. Brand contributed to the study design and data analysis and interpretation. A. A. Florindo and Antonio García-Hermoso contributed to the study design and reviewed the final version. J. Mota and A. C. A. Gaya reviewed the final version.

## Additional informations

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## Acknowledgments

Scholarship from the Brazilian Graduate Studies Coordinating Board (CAPES). Research fellowship from the Brazilian National Research Council (CNPq; 305200/2013-5). J. Mota was supported by grants from the Portuguese Foundation for Science and Technology (FCT; SFRH/BSAB/142983/2018 and UID/DTP/00617/2019), as well as Scholarship Program of Santander Universities 2018.

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## Resumo

O estudo teve como objetivo verificar se a densidade residencial e a conectividade entre ruas são mediadores da associação entre fatores ambientais percebidos e deslocamento ativo casa-escola (DAE) em adolescentes brasileiros. Foi um estudo transversal com uma amostra randomizada de 1.130 adolescentes (52,7% do sexo feminino) entre 14 e 20 anos de idade, de Porto Alegre, Rio Grande do Sul, Brasil. Os adolescentes informaram seu modo de deslocamento casa-escola (ida e volta) através de um questionário, além dos atributos ambientais percebidos, de acordo com a Neighborhood Environment Walkability Scale for Youth (NEWS-Y). A densidade residencial e a conectividade entre ruas foram medidas por sistemas de informação geográfica (SIG), dentro de um raio de 1km da rede viária em torno do endereço residencial do participante. Foram ajustados modelos de regressão de acordo com os procedimentos para análises de mediação. Os resultados mostraram que a densidade residencial é um mediador da associação entre os fatores ambientais percebidos e o DAE, inclusive a diversidade do uso do solo (EI = 0,114; IC95%: 0,130, 0,311; 32% de mediação), infraestrutura para atividades de lazer na vizinhança (EI = 0,064; IC95%: 0,034, 0,105; 15% de mediação) e acesso a serviços (EI = 0,045; IC95%: 0,006, 0,104; 14% de mediação). A conectividade entre ruas não mostrou correlação com DAE, portanto não foi testado no modelo de mediação. Conclui-se que a densidade residencial é um mediador da relação entre fatores ambientais percebidos e DAE.

*Ambiente Construído; Transportes; Exercício Físico; Estudantes*

## Resumen

El objetivo fue verificar si la densidad poblacional y la conectividad entre calles son mediadores en la asociación entre los factores ambientales percibidos y el desplazamiento activo a la escuela (DAE) en adolescentes brasileños. Se trata de un estudio transversal, con una muestra aleatoria de 1.130 adolescentes (52,7% chicas), con una edad comprendida entre los 14 y los 20 años de edad, de Porto Alegre, Río Grande do Sul, Brasil. Los adolescentes autoinformaron su modo habitual de desplazamiento “a” y “desde” la escuela, usando un cuestionario y las características ambientales percibidas mediante el Neighborhood Environment Walkability Scale for Youth (NEWS-Y). La densidad poblacional y conectividad entre las calles se midieron mediante los sistemas de información geográfica (GIS), dentro de una red vial delimitada por un radio de 1km alrededor de la dirección residencial del participante. Los modelos de regresión se ajustaron según los procedimientos para el análisis de mediación. Los resultados mostraron que la densidad poblacional es un a mediador en la asociación entre los factores ambientales percibidos y la DAE, incluyendo el uso del suelo para diversos fines (EI = 0,114; IC95%: 0,130, 0,311; 32% mediación), instalaciones recreativas en el barrio (EI = 0,064; IC95%: 0,034, 0,105; 15% mediación), y acceso a los servicios (EI = 0,045; IC95%: 0,006, 0,104; 14% mediación). Conectividad entre calles que no mostraron correlación con DAE, por consiguiente, no fue probado en el modelo de mediación. En conclusión, la densidad poblacional es un mediador en la relación entre los factores ambientales percibidos con DAE.

*Entorno Construido; Transportes; Ejercicio Físico; Estudiantes*

Submitted on 03/Apr/2020

Final version resubmitted on 30/Jul/2020

Approved on 04/Sep/2020