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Perceived and objective measures of neighborhood environment: Association with active commuting to school by socioeconomic status in Brazilian adolescents

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RESUMO

Introdução: O deslocamento para a escola é influenciado por fatores ambientais que são específicos de cada país. O presente estudo teve como objetivo analisar a associação entre deslocamento ativo de/para escola (DAE) com medidas percebidas e objetivas dos fatores ambientais do bairro, assim como avaliar a influência do nível socioeconômico (NSE) em adolescentes Brasileiros.
Métodos: Estudo transversal, com amostra aleatória de 1130 adolescentes (47,3% meninos), com idades entre 14 e 20 anos, da cidade de Porto Alegre-Brasil. DAE e NSE foram avaliados por questionário e os fatores do ambiente percebido através da *Neighborhood Environment Walkability Scale for Youth* (NEWS-Y). Fatores objetivos do ambiente construído foram mensurados usando o Sistema de Informações Geográficas, pela rede de ruas nos buffers de 0,5 km e 1,0 km em torno do endereço residencial do participante. A análise dos dados foi realizada por meio de modelos de regressão linear generalizada.
Result: ados: A associação entre DAE com medidas percebidas e objetivas dos fatores ambientais no bairro de adolescentes nos buffers de 0,5 km e 1,0 km foram: uso misto do solo, instalações de recreação no bairro, existência de ciclovias e densidade residencial. Além disso, a existência de parques/praças foi associada com DAE apenas no buffer de 0,5 km. A existência de ciclovias nos buffers de 0,5 km e 1,0 km foi associada com DAE em todos os NSE. O uso misto do solo e as instalações de recreação no bairro foram associados com DAE apenas no NSE médio em ambos buffers. Ainda, foi encontrada associação entre o uso misto do solo com DAE no buffer de 0,5 km no NSE baixo e alto.
Conclusão: DAE foi associado com o uso misto do solo, instalações de recreação no bairro, existência de parques/praças e ciclovias e densidade residencial em adolescentes Brasileiros. NSE é um fator importante ao considerar DAE e fatores ambientais.

RESUMEN

Introducción: El desplazamiento a la escuela es influenciado por factores ambientales específicos de cada país. El presente estudio tuvo como objetivo analizar la asociación entre los desplazamientos activos de la/desde la escuela (DAE) con las medidas percibidas y objetivas de los factores ambientales del vecindario, así como evaluar la influencia del estado socioeconómico (ESE) en los adolescentes Brasileños.
Métodos: Estudio transversal con muestra aleatoria de 1130 adolescentes (47,3% niños), edades entre 14 y 20 años, de la ciudad de Porto Alegre-

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Brasil. DAE y ESE se evaluaron mediante cuestionario y los factores ambientales percibidos a través de *Neighborhood Environment Walkability Scale-Youth* (NEWS-Y). Factores ambientales construidos objetivamente, los cuales fueron medidos usando Sistemas de Información Geográfica, dentro de los límites de la red vial situados entre 0,5 km y 1 km alrededor de la dirección residencial del participante. El análisis de datos se realizó utilizando modelos de regresión lineal generalizados.

Result: ados: La asociación entre DAE con medidas percibidas y objetivas de los factores ambientales del vecindario de los adolescentes en zonas de amortiguación 0,5 km y 1,0 km fueron: mezcla de uso del suelo, instalaciones de recreación en el vecindario, ciclovías y densidad residencial. Adicionalmente, existencia de parques/plazas fue asociado con DAE solo en zona de amortiguación 0,5 km. Existencia de ciclovías en zona de amortiguación 0,5 km y 1,0 km se asoció con SCA en todos ESE. Mezcla de uso del suelo y las instalaciones de recreación del vecindario se asociaron con DAE solo en ESE medio en ambas zonas. Además, se encontró asociación entre mezcla de uso del suelo y DAE en zona de amortiguación 0,5 km para ESE bajo y alto.

Conclusión: DAE fue asociado con mezcla de uso del suelo, instalaciones recreativas de vecindario, existencia de parques/plazas, ciclovías y densidad residencial en adolescentes Brasileños. ESE es factor importante a considerar al estudiar DAE y factores ambientales.

1. Background

Active commuting to/from school (ACS) (i.e. walking or cycling to and from school) has the potential to contribute substantially to physical activity and health (Larouche et al., 2014). Studies developed in different countries, such as Portugal (Pizarro et al., 2016), Sweden and Estonia (Chillón et al., 2010), shows that adolescents who walk or cycle to school have higher daily levels of physical activity than those who go to school by car or bus. Besides, ACS is associated with better physical fitness and a lower incidence of metabolic syndrome in girls (Ramírez-Vélez et al., 2017), and with better profile of high density lipoprotein cholesterol and waist circumference in school children (Pizarro et al., 2013).

Ecological models have been recognized as an important approach to understand and explain physical activity behavior, considering they postulate that human behavior involve different scales of influence (individual, social, physical environmental and policy) and the interaction between them (Sallis et al., 2006). Regarding the built environment, a recent systematic review showed that creating new infrastructure for walking, cycling and public transportation could induce active modes of transportation (Kärmeniemi et al., 2018). Also, some studies held in developed countries have found that highest rates of walkability index, street connectivity and neighborhood safety are associated with ACS in adolescents (De Meester et al., 2013; D'Haese et al., 2015; Duncan et al., 2016). Winters et al. (2011) showed that routes away from traffic noise and pollution, routes with beautiful scenery and paths separated from traffic are the motivators for bicycling. Another environment factor that could intervene on active commuting is topographic characteristics of the city (Nixon, 2012).

In order to reduce private motor vehicle and to enhance active commuting, a Lancet series identified some interventions, highlighting the following factors: destination accessibility, employment distribution, parking policies, pedestrian- and cycling-friendly street networks, residential density, public transportation availability, mixed land use and desirability of active travel modes (Giles-Corti et al., 2016). It is important to consider that, compact cities that involve these characteristics are benefited with health gains in terms of diabetes, respiratory disease and cardiovascular disease (Stevenson et al., 2016).

The influence of socioeconomic status (SES) is another issue that must be taken into account regarding the relationship between ACS and environmental factors. Molina-García et al. (2014) has shown that low SES is associated with higher active commuting in Spanish students. More recently, the same author indicated that children attending schools located in lower SES neighborhoods reported more active commuting than those attending schools in higher SES (Molina-García and Queralt, 2017). In Brazil, there are only two studies investigating this topic in adolescents, Silva et al. (2018) showed that SES is a moderator in the association between the perceived environment and ACS. Besides, it was found associations between commuting physical activity with street lighting and presence of cycle lanes only among the intermediate SES tertile (Silva et al., 2017).

Commuting to school is a daily activity, highly influenced by environmental and cultural factors that are specific for each country and geographical area. To assess environmental characteristics related to neighborhood walkability, both perceived and observed measures can be used (Hino et al., 2010). However, it is not clear how strong the agreement between both types of measure is. Thus, studies have been suggesting to include both objective and perceived measures of the built environment, because they give different information, although complementary (Hinckson et al., 2017).

Indeed, the above mentioned aspects should be more explored in Brazilian adolescents considering that to the best of our knowledge, this is one of the first studies conducted with environmental characteristics objectively and subjectively measured, in addition to investigate the role of SES. We emphasize that knowing the relationship between environmental factors and ACS by SES is important in Brazil where there is not enough evidence about these aspects, especially considering that this is one of the most unequal countries in the world. Therefore, the present study aimed to analyze the association between ACS with perceived and objective measures of neighborhood environmental factors, as well as to evaluate the influence of SES in Brazilian adolescents.

2. Methods

2.1. Study design

This is a cross sectional study, with a quantitative approach, developed in Porto Alegre, Brazil. The city population is approximately 1.4 million inhabitants (year 2010), a territorial area of 496,681 km^2 and a demographic density of 2837.53 inhabitants/km^2 (IBGE, 2010). Porto Alegre is one of the most forested capitals of the country, it has approximately 630 squares, 8 public parks and 3 conservation units according to data from the Planning Environment Department.

The population was composed of approximately 34,645 high school students, from 71 public schools (INEP, 2014). They were allocated in the following regions: 8057 north; 6423 south; 4268 east; and 15,897 center.

In order to calculate the sample size, the following criteria were considered: a) estimated population of 34,645 students (N); b) proportion of subjects in the target population 50% (p); c) complementary percentage of 100 minus p value (q); d) degree of confidence of 2 standard deviations (S); and e) acceptable sampling error of 3% (e). After the adoption of these criteria and accordingly the formula presented below, it was estimated that 1077 students should be evaluated. However, to avoid probable difficulties with the sample loss, an increase of 5% was assumed, totaling 1130 youth. This formula was used to have a sample that represents the study population. This calculation was performed using the formula to have a representative sample of the population. The power of the test was tested through the software G*power version 3.1.9.2, for the statistical analysis used in the study, the value of the power of the test was 1.0.

$$n = S^2.\ p.\ q.\ N\ /\ e^2\ (N - 1)\ +\ (S^2.\ p.\ q)$$

Sample selection considered the proportion of youth enrolled in the schools by region. Thus, the sample was composed of: 263 students from 4 schools in the north region (23.26%); 518 students from 7 schools in the central region (45.88%); 140 students from 2 schools in the east region (12.32%); and 209 students from 3 schools in the south region (18.54%).

The sample selection was realized by multiple phases' procedure (Gaya et al., 2008). Initially, the schools were selected, accordingly to each region, and then, in the schools, the high school classes were selected, randomly. A number was assigned for each school and all numbers were placed in a box, mixed and randomly reelected one by one. Then, data was collected in one class belonging to first, second and third year from the high school.

The students from classes selected 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) handing in the consent document signed by a parent or guardian; and c) signing the assent document manifesting will to participate. We emphasize that according to Sawyer et al. (2018) a definition of 10–24 years corresponds more closely to adolescent growth and popular understandings of this life phase, thus we use the term adolescents, even when some students were over 18 years of age.

Data collection was performed during eight month in 2017, this period corresponds in three different seasons (winter, fall and spring), however we verified that there was no difference in ACS between the seasons ($F = 0.41$; $p = 0.66$). First, the researcher went to the selected schools, explained 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. Questionnaires were filled out during a regular class, corresponding to approximately 45 min.

2.2. Measurements procedures

2.2.1. Mode of commuting to and from school

Students completed a questionnaire, supervised by researchers at school. To assess ACS, subjects answered the question 'How do you usually go to/go back from school?' (Normalmente como você se desloca para ir e voltar da escola?). This 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 (Herrador-Colmenero et al., 2014). Response choices were (1) by walking, (2) by bicycle, (3) by bus, (4) by car and (5) other. Active commuting was defined as walking or cycling to school, while, passive commuting was defined as traveling to school by bus or by car. The students who answered other, should describe which transportation they used to school, so the answers were individually analyzed and defined as active or passive commuting.

2.2.2. Perceived environmental factors

To measure perceived neighborhood environmental factors, the version of the Neighborhood Environment Walkability Scale for Youth (NEWS-Y) (Rosenberg et al., 2009), validated in Brazil (Lima et al., 2013) was used. This questionnaire evaluates perceived environment factors that may influence youth PA (Rosenberg et al., 2009). Questions were considered according to the following dimensions, proposed by the NEWS-Y scoring guidelines (Sallis, 2009): Land use mix-diversity (perception of distance in minutes from home to a variety of more common destinations, such as shops or school), neighborhood recreation facilities (perceived distance in minutes from the student house, walking to a variety of places for physical activity practice, such as walking/running track or large public park), access to services, street connectivity, places for walking, neighborhood aesthetics, neighborhood safety and crime safety. More information about the questions can be found elsewhere Lima et al. (2013), Rosenberg et al. (2009) and website James F. Sallis athrough the link < http://sallis.ucsd.edu/Documents/Measures_documents/NEWS_Y_adolescent.pdf > .

For land use mix (diversity) and neighborhood recreation facilities, the answers options were: 1–5min, 6–10min, 11–20min, 21–30min, more than 30 min and don't know/there isn't. The option 'don't know' response was coded as a "more than 30 min" because if it is not known whether the facility is within walking distance, the actual walk is likely more than 31 min (Sallis, 2009). All items were reverse coded and employ mean values. Also, the NEWS-Y guidelines indicate an alternative scoring to tally the number of stores or facilities within a 5, 10, or 20-min walk, which was considered "near from home" (Sallis, 2009).

All the 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). These answers were dichotomized into agree and disagree for descriptive analyses. All determinants were calculated following the NEWS-Y scoring protocol (Sallis, 2009) with a higher score, indicating better conditions for commuting to school.

2.2.3. Objective environment factors

Students addresses, reported in the questionnaire were geocoded in the Geographic System Information (GIS) through ArcMap 10.3.1 software. A shapefile of the streets, parks and squares provided by the Municipal Department of Urbanism (SMUrb) and environment and sustainability (SMAM) of Porto Alegre – RS was used for the analysis.

Buffers within 0.5 km and 1 km of the participants' homes, reachable by the street network, were defined to estimate accessible neighborhood features. These buffers were used because the methodology of a large study, International Physical Activity and Environment Network (IPEN), involving different countries of the world, including Brazil, applied these buffers sizes (Sallis et al., 2016). Thus, the following variables were used: existence of parks and squares (existence of parks and squares in buffer); existence of bicycle path (existence of bicycle path in buffer); residential density (number of residences within each buffer); density of blocks (number of blocks within each buffer); average size of the blocks (average size of streets/blocks within each buffer); and connectivity between streets (intersection number of streets in buffer).

The walkability concept employed in the IPEN project methodology, comes from the transportation and urban planning fields and

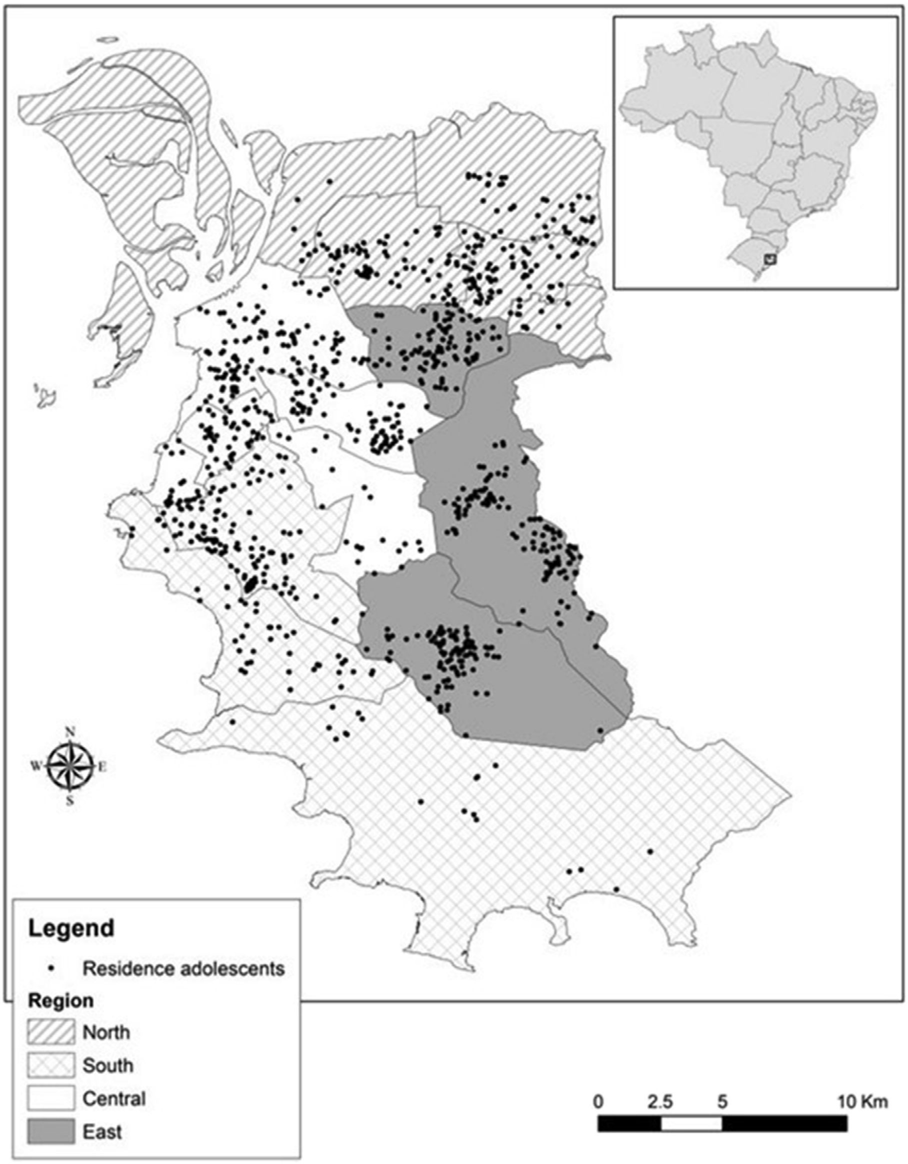

Fig. 1. Georeference of participants of the sample in Porto Alegre-RS(n = 1010).

is concerned with environments that primarily encourage people to walk or bike for transportation (IPEN, 2012; Sallis et al., 2016). "Walkable" neighborhoods in this context are the ones where it is easy to walk or bike directly to multiple destinations (IPEN, 2012). Thus, connectivity between streets and residential density were determined and z-scores were calculated. The walkability index was calculated as follows: walkability = (2* z-score connectivity between streets) + (z-score residential density). Considering that no data of "retail floor area ratio and land use mix" were available for the present study, the original formula of Frank et al. (2010) was adapted. Also, Koohsari et al. (2016) proposed an alternative walkability index with two variables (population density and a space syntax measure of street integration) and found a high correlation with original walkability index in walking for transport.

2.2.4. Socioeconomic status

Socioeconomic status was assessed through a National commonly used index which include a number of owned items at the adolescents' residences (for example, refrigerator, notebook and microwave) and the level of schooling of the parent or guardian, according to the criteria established by the Brazilian Association of Research Companies (Abep, 2015). Then, students answered questions about the existence and quantity of items in their home and information about the level of schooling of the parent or guardian, where does the house water come from (well or spring, general distribution register or other means) and the street of his home (asphalted/paved or earth/gravel). For each answer, a score was constructed and the sum of the points was done to identify each student's economic class (Abep, 2015). Then adolescents were classified into the following economic classes: low (1° tertile), middle (2° tertile) and high (3° tertile). Sex and age were assessed using a questionnaire.

2.3. Statistical analysis

Descriptive data are shown as absolute and relative values (sex, socioeconomic status, commuting to school, perceived environmental factors and existence of bicycle path, parks and squares), means and standard deviations (age, scores dimensions of perceived environmental factors and built environmental factors in 0.5 km and 1 km buffers). To verify internal consistency from NEWS-Y dimensions' variables Cronbach Alpha (0.89) was calculated: 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).

Then, the associations between ACS with perceived and objective measures of neighborhood environmental factors, were investigated through generalized linear regression. The analyzes were split in two models: variables of the perceived environment adding objective built environment with 0.5 km buffers (model 1); and perceived environment adding objective built environment with 1 km buffers (model 2). Also, the analyzes were stratified by SES for each buffer. Both analyzes were adjusted for sex, age, socioeconomic status and class. We tested additional adjustment for the environmental variables considering collinearity between them (rho ≥ 0.60). Finally, alpha values (< 0.05) and confidence intervals (95%) were presented. All the analyses were performed in the software IBM SPSS version 22.0 (SPSS, Inc., Chicago, Illinois, USA).

3. Results

The study sample comprised 1130 youth living in Porto Alegre-RS, 1010 were geocoded for built environmental analyses (Fig. 1). Sample losses were caused by insufficient address information and incompatibilities in the street network, leading to some critical constraints for an integration of the space syntax within GIS.

Descriptive characteristics of the sample are presented in Table 1. Five hundred and thirty four (534) boys and 596 girls, aged 14–20 years participated in the study. 56.2% of youth were classified as middle-income status. Only 30.2% actively commuted to school. Furthermore, questions regarding perceived environmental factors and the scores of each dimension, as well as, questions of built environment factors, from 0.5 km and 1 km buffers, are described in Table 1.

Table 2 shows the results of the association between perceived and objective measures of neighborhood environment factors with ACS in adolescents. The results indicated that ACS was associated with land use mix, neighborhood recreation facilities, existence of parks, squares and bicycle paths and residential density in 0.5 km buffers (model 1). Regarding 1 km buffer (model 2), it was observed that ACS was associated with land use mix, neighborhood recreation facilities, existence of bicycle paths and residential density.

The association between perceived and objective neighborhood environment factors with ACS by socioeconomic status in adolescents is presented in Table 3. Results showed that the existence of bicycle path in 0.5 and 1 km buffers was associated with ACS in all SES. In addition, neighborhood recreation facilities were associated with ACS in middle SES in both buffers. An association between land use mix and ACS in all SES was also found for 0.5 km buffer While in the 1 km buffer a higher perception of land use mix increased the odds of ACS only in middle SES.

4. Discussion

The results showed that when considering the perceived and objective measures of the environment, ACS was associated with perceived land use mix and neighborhood recreation facilities, as well as objectively measured existence of bicycle paths and residential density in 0.5 km and 1 km buffers around adolescents' home. Existence of parks and squares was also associated with ACS but only in 0.5 km buffers. Concerning the influence of SES, it was found an association between land use mix, neighborhood recreation facilities and existence of bicycle path with ACS in both buffers.

Regarding the perceived environmental factors, our data showed that the shortest distance from the adolescent's residence to

Table 1
Sample's characteristics, descriptive and occurrence analysis.

Variables	N(%)	Mean(SD)
Age (years)	–	16.49(1.05)
Sex		
Boys	534(47.3)	–
Girls	596(52.7)	–
Socioeconomic status (n = 1114)		
High	410(36.8)	–
Middle	336(30.2)	–
Low	368(33.0)	–
Physical activity (n = 1123)		
Commuting to school (active)	339(30.2)	–
Perceived Environmental Factors		
Land use mix - diversity *(proportion: near from home)* (n = 1129)		
1.Convenience/corner store/small grocery store/bodega	1034(91.5)	–
2. Supermarket	951(84.2)	–
3. Hardware store	892(78.9)	–
4. Fruit/vegetable market	844(74.7)	–
5. Laundry or dry cleaners	347(30.7)	–
6. Clothing store	525(46.5)	–
7. Post office	324(28.7)	–
8. Library	173(15.3)	–
9. Elementary school	883(78.1)	–
10. Middle or high school	610(54,0)	–
11. Book store	221(19.6)	–
12. Fast food restaurant	588(52.0)	–
13. Coffee place	446(39.5)	–
14. Bank/credit union	581(51.4)	–
15. Non-fast food restaurant	643(56.9)	–
16. Video store	442(39.1)	–
17. Pharmacy/drug store	882(78.1)	–
18. Hairdressers/barber shop	935(82.7)	–
19. Any offices/worksites	293(25.9)	–
20. Bus, subway or train stop	1049(92.8)	–
21. Score land use mix – diversity	–	3.56(0.89)
Neighborhood recreation facilities *(proportion: near from home)* (n = 1129)		
1. Indoor recreation or exercise facility (public or private)	512(45.3)	–
2. Beach, lake, river, or creek	142(12.6)	–
3. Bike/hiking/walking trails, paths	336(29.7)	–
4. Basketball court	797(70.5)	–
5. Other playing fields/courts (like soccer, football, etc)	499(44.2)	–
6. Private sports clubs	336(29.7)	–
7. Boys and girls club	540(47.8)	–
8. Swimming pool	342(30.4)	–
9. Walking/running track	367(32.5)	–
10. School with recreation facilities open to the public	266(23.5)	–
11. Small public park	838(74.2)	–
12. Large public park	407(36.0)	–
13. Public playground with equipment	542(48.0)	–
14. Public open space that is not a park	448(39.6)	–
15. Score neighborhood recreation facilities	–	2.86(1.05)
Access to services *(proportion: agree)* (n = 1130)		
1. Stores are within easy walking distance of my home	821(72.7)	–
2. Parking is difficult in local shopping areas	527(46.6)	–
3. There are many places to go within easy walking distance of my home	819(72.5)	–
4. From my home, it is easy to walk to a transit stop alone or with someone	1018(90.1)	–
5. The streets in my neighborhood are hilly, making my neighborhood difficult to walk in (alone or with someone)	582(51.5)	–
6. There are major barriers to walking in my local area that make it hard to get from place to place	246(21.8)	–
7. Score access to services	–	2.46(0.49)
Street connectivity *(proportion: agree)* (n = 1130)		
1. The distance between intersections (where streets cross) in my neighborhood is usually short	662(58.6)	–
2. The streets in my neighborhood do not have many cul-de-sacs	621(55.0)	–
3. There are many different routes for getting from place to place in my neighborhood	786(69.6)	–
4. Score street connectivity	–	2.74(0.68)
Places for walking *(proportion: agree)* (n = 1130)		
1. There are sidewalks on most of the streets in my neighborhood	852(75.4)	–
2. Sidewalks are separated from the road/traffic in my neighborhood by parked cars	682(60.4)	–
3. There is grass/dirt between the streets and the sidewalks in my neighborhood	579(51.2)	–
4. Score places for walking	–	275(0.69)
Neighborhood Aesthetics *(proportion: agree)* (n = 1130)		

(*continued on next page*)

Table 1 (*continued*)

Variables	N(%)	Mean(SD)
1. There are trees along the streets in my neighborhood	957(84.7)	–
2. There are many interesting things to look at while walking in my neighborhood	415(36.7)	–
3. There are many beautiful natural things to look at in my neighborhood (e.g., gardens, views)	404(35.8)	–
4. There are many buildings/homes in my neighborhood that are nice to look at	643(56.9)	–
5. Score neighborhood aesthetics	–	2.55(0.72)
***Neighborhood safety** (proportion: agree)* (n = 1129)		
1. There is so much traffic along nearby streets that it makes it difficult or unpleasant to walk in my neighborhood	485(42.9)	–
2. The speed of traffic on most nearby streets is usually slow	658(58.2)	–
3. Most drivers go faster than the posted speed limits in my neighborhood	590(52.2)	–
4. My neighborhood streets have good lighting at night	593(52.5)	–
5. Walkers and bikers on the streets in my neighborhood can be easily seen by people in their homes	696(61.6)	–
6. There are crosswalks and signals to help walkers cross busy streets in my neighborhood	595(52.7)	–
7. When walking in my neighborhood there are a lot of exhaust fumes	432(38.3)	–
8. Score neighborhood safety	–	2.38(0.46)
***Crime safety** (proportion: agree)* (n = 1129)		
1. There is a high crime rate in my neighborhood	802(71.0)	–
2. The crime rate in my neighborhood makes it unsafe to go on alone or with someone at night	795(70.4)	–
3. I am worried about being outside alone around my home because I am afraid of being taken or hurt by a stranger	377(33.4)	–
4. I am worried about being outside with a friend around my home because I am afraid of being taken or hurt by a stranger	510(45.1)	–
5. I am worried about being or walking alone or with friends in my neighborhood and local streets because I am afraid of being taken or hurt by a stranger	581(51.4)	–
6. I am worried about being in a local/nearby park because I am afraid of being taken or hurt by a stranger	732(64.8)	–
7. Score crime safety	–	2.59(0.81)
Objective Environmental Factors (n = 1010)		
Existence of parks and squares – 0.5 km buffers (proportion: yes)	609(60.3)	–
Existence of parks and squares –1km buffers (proportion: yes)	867(85.8)	–
Existence of bicycle path – 0.5 km buffers (proportion: yes)	122(10.8)	–
Existence of bicycle path – 1 km buffers (proportion: yes)	242(24.0)	–
Residential density −0.5 km buffers	–	2757.03(1452.26)
Residential density –1km buffers	–	7257.91(4106.12)
Connectivity between streets –Number of intersections (0.5 km buffers)	–	50.77(31.39)
Connectivity between streets – Number of intersections (1 km buffers)	–	186.02(103.45)
Blocks density - 0.5 km buffers	–	8657.89(3570.94)
Blocks density - 1 km buffers	–	29198.02(12181.17)
Average size of the blocks - 0.5 km buffers (meters)	–	122.98(84.83)
Average size of the blocks - 1 km buffers (meters)	–	114.97(42.17)
Walkability index[a] – 0.5 km buffers	–	0.00(0.52)
Walkability index[a] – 1 km buffers	–	0.00(0.57)

[a] Walkability index: Standardized variables (transformed into Z-scores).

places like bookstores, supermarkets, and other land use mix-diversity places, as well as distance to neighborhood recreation facilities, such as less distance to the square, parks, soccer fields and clubs, were associated with ACS. In this perspective, a research carried out in Belgium is in agreement with the results of the present study, showing that the land use mix is associated with more min/day ACS (De Meester et al., 2013). Several reasons may underline this association, for example it might be that youth are so used to walk to the different places in the neighborhood, that they choose to active commute to school, in addition to safety perception neighborhood and short distance to school. On the other hand, active commuting was positively associated with "having places they like to go to" but inversely related with "places with opportunities to practice", in adolescents from the northeastern of Brazil (Mendonça et al., 2017), which go against to our data. However, this inverse association may be due different assessment methods that were used for active commuting.

Unexpectedly, we found no association between safety perceptions and ACS. Previous research in Brazil has found a relationship of perceiving the neighborhood as not violent with active commuting (Mendonça et al., 2017). Moreover, a systematic review, included mainly by studies in North America and Australia, has suggested that safety measures were associated with ACS (D'Haese et al., 2015). In fact, different studies have shown that safety perception is as an interveniet factor for physical activity engagement (D'Haese et al., 2015; Janssen, 2014; Rees-punia et al., 2017) but not in ours. However, we emphasize that each place has its specificities and people perceive safety of the neighborhood differently, which may influence this assotiations.

Considering the objectively measured built environmental factors, the results of the present study showed that existence of bicycle paths and residential density were associated with ACS in both the 0.5 km and 1 km buffers around adolescents' residence. On the other hand, existence of parks and squares was only associated with ACS in the 0.5 km buffer. In line with our results, reviews about this topic (Giles-Corti et al., 2009; Pont et al., 2009; Sallis et al., 2012) showed that built environmental factors, such as, urban density, neighborhoods with mixed-use planning, recreation facilities and walk or bike paths are associated with active commuting or walking. Smith et al. (2017) demonstrated a positive effect of provision of quality parks and playgrounds, and installation or improvements in infrastructure for active transport. Also, a recent review study found that creating new infrastructure for walking,

Table 2
Association between perceived and objective neighborhood environment factors with active commuting to school in adolescents (n = 770).

Perceived Environmental Factors	Active commuting to school					
	Model 1[b]			Model 2[b]		
	OR	CI-95%	p	OR	CI-95%	p
Land use mix – diversity	1.63	(1.32 2.03)	< **0.001**[c]	1.50	(1.21 1.88)	< **0.001**[d]
Neighborhood recreation facilities	1.36	(1.14 1.62)	< **0.001**[c]	1.38	(1.15 1.64)	< **0.001**[d]
Access to services	1.10	(0.76 1.60)	0.57	1.15	(0.80 1.67)	0.43
Street connectivity	0.98	(0.73 1.21)	0.66	0.97	(0.76 1.25)	0.86
Places for walking	0.79	(0.61 1.02)	0.07	0.89	(0.69 1.15)	0.39
Neighborhood aesthetics	1.03	(0.80 1.31)	0.80	1.02	(0.80 1.30)	0.84
Neighborhood safety	1.05	(0.71 1.56)	0.79	1.13	(0.76 1.67)	0.53
Crime safety	1.10	(0.88 1.38)	0.36	1.07	(0.85 1.34)	0.54
Objective Environment Factors	(0.5 km - buffers)			(1 km – buffers)		
Existence of parks and squares						
No	1			1		
Yes	1.50	(1.02 2.20)	**0.03**	1.40	(0.76 2.57)	0.26
Existence of bicycle path						
No	1			1		
Yes	2.01	(1.26 3.23)	**0.003**	2.56	(1.75 3.75)	< **0.001**
Residential density[a]	1.19	(1.01 1.42)	**0.04**[c]	1.31	(1.07 1.60)	**0.008**[d]
Connectivity between streets[a]	0.85	(0.69 1.04)	0.12[c]	0.90	(0.73 1.10)	0.31[d]
Blocks density[a]	1.10	(0.91 1.32)	0.30[c]	1.21	(0.98 1.49)	0.07[d]
Average size of the blocks[a]	0.93	(0.75 1.15)	0.53	0.82	(0.64 1.06)	0.13[d]
Walkability[a]	0.96	(0.89 1.04)	0.96[c]	0.98	(0.90 1.07)	0.75[d]

[a] Standardized variables (transformed into z-scores).
[b] Adjusted for sex, age, socioeconomic status and class.
[c] Additionally adjusted for model 1[a], without the environmental variables that present high colinearity (rho ≥ 0.60). Land use mix – diversity showed high correlation with neighborhood recreation facilities (rho = 0.63). Walkability showed high correlation with residential (rho = 0.78), blocks (rho = 0.85) density and connectivity between streets (rho = 0.89). Connectivity between streets showed high correlation with blocks density (rho = 0.78) (0.5 km buffers).
[d] Additionally adjusted for model 2[a], without the environmental variables that present high colinearity (rho ≥ 0.60). Land use mix – diversity showed high correlation with neighborhood recreation facilities (rho = 0.63). Walkability showed high correlation with residential (rho = 0.81), blocks (rho = 0.90) density and connectivity between streets (rho = 0.92). Residential density showed high correlation with blocks density (rho = 0.78). Connectivity between streets showed high correlation with residential (rho = 0.60), blocks (rho = 0.82) density and average size of the blocks (rho = 0.70) (1 km buffers).

cycling and public transportation is associated with active commuting (Kärmeniemi et al., 2018).

Our findings are in line with the aforementioned review studies, where existence of parks, squares and bicycle paths and residential density were associated with ACS in adolescents. However, studies are scarce regarding objective measures of built environment and its relation with ACS in Brazilian adolescents. These aspects have been explored in adult populations and results indicate that neighborhoods with greater density of employment factors, and greater proportion of residential and commercial areas were associated with walking for transport (Hino et al., 2014; Yang et al., 2017).

SES emerged as a significant variable in this research study. Our findings showed that adolescents that have bicycle path in 0.5 and 1 km buffers around the residence had more odds to actively commute to school in all SES. Thus, we highlight the importance of a cycle path for ACS in all adolescents, independently of SES. There are limited references regarding this issue in adolescents. It was found in south of Brazil an association between active commuting and presence of cycle lanes, in addition to street lighting only in middle SES (Silva et al., 2017).

In the 0,5 km buffer, adolescents with better perception of land use mix in were more likely to active commute to school in all SES levels, while in the 1 km buffer this association remained significant only in middle SES. Perception of a shorter distance to neighborhood recreation facilities was also associated with ACS in both buffers, but only in middle SES. As generally studies that investigate the relationship between these variables not consider the role of SES, our findings bring new information regarding this topic. Indeed, we observed that a wide range of infrastructure around adolescent's residence, enhances the probability of ACS in all SES.

The main strengths of this study are that we provide a combined assessment of the contribution of subjective and objective measures of environment characteristics and its association with ACS. Further we also consider the influence of SES. In addition, this study included a large sample of Brazilian adolescents, which is relevant once most studies in Brazil were developed with adults. Based on this, as practical applications, policy makers will have access to concrete data to help them decide on how to allocate resources and on what to invest. Furthermore, students will have the opportunity of using pleasant and high-quality environments that provide better conditions for active commuting, and this will contribute to their health.

This study has also some limitations that should be mentioned. The cross-sectional nature did not allow for causal inferences. Commuting to school was self-reported, and we were not able to determine the frequency, duration and intensity of commuting.

Table 3
Association between perceived and objective neighborhood environment factors with active commuting to school by socioeconomic status in adolescents.

Perceived Environmental Factors	Active commuting to school					
	Model 1[b]			Model 2[b]		
		SES (n = 1114)			**SES** (n = 1114)	
	Low (n = 368)	**Middle** (n = 336)	**High** (n = 409)	**Low** (n = 368)	**Middle** (n = 336)	**High** (n = 409)
	OR (CI-95%)	OR (CI-95%)	OR (CI-95%)	OR (CI-95%)	OR (CI-95%)	OR (CI-95%)
Land use mix – diversity	**1.70 (1.03 2.80)**	**1.75 (1.19 2.57)**[c]	**1.51 (1.01 2.26)**	0.69 (0.42 1.13)	**1.73 (1.16 2.59)**[c]	1.34 (0.90 2.02)
Neighborhood recreation facilities	1.16 (0.77 1.77)	**1.47 (1.09 1.99)**[c]	1.08 (0.76 1.54)	0.78 (0.51 1.19)	**1.46 (1.07 1.98)**[c]	1.13 (0.80 1.60)
Access to services	0.63 (0.32 1.28)	1.49 (0.74 2.97)	1.21 (0.65 2.26)	1.52 (0.75 3.06)	1.68 (0.82 3.41)	1.15 (0.61 2.16)
Street connectivity	0.82 (0.53 1.29)	1.33 (0.82 2.17)	0.94 (0.63 1.40)	1.25 (0.79 1.97)	1.37 (0.84 2.23)	0.90 (0.59 1.35)
Places for walking	0.75 (0.49 1.15)	0.72 (0.44 1.15)	1.17 (0.75 1.83)	1.28 (0.85 1.93)	0.64 (0.35 1.14)	1.12 (0.70 1.78)
Neighborhood aesthetics	1.30 (0.83 2.02)	1.08 (0.68 1.73)	0.78 (0.51 1.18)	0.80 (0.50 1.27)	1.09 (0.68 1.75)	0.81 (0.52 1.24)
Neighborhood safety	1.52 (0.69 3.33)	1.15 (0.55 2.42)	0.85 (0.46 1.57)	0.66 (0.30 1.44)	1.28 (0.61 2.69)	0.76 (0.40 1.43)
Crime safety	0.92 (0.62 1.37)	1.54 (0.98 2.39)	1.01 (0.69 1.49)	1.07 (0.72 1.59)	1.49 (0.96 2.31)	1.05 (0.71 1.54)
Objective Environment Factors	(0.5 km - buffers)			(1 km – buffers)		
Existence of parks and squares						
No	1			1	1	1
Yes	1.38 (0.65 2.93)[c]	1.55 (0.75 3.20)	1.53 (0.79 2.97)	1.16 (0.61 4.28)	0.88 (0.29 2.65)	1.10 (0.32 3.75)
Existence of bicycle path						
No	1			1	1	1
Yes	**2.43 (1.00 5.94)**	**2.72 (1.08 6.82)**	**1.39 (1.01 2.18)**	**2.12 (1.05 4.29)**	**2.09 (1.04 4.19)**	**2.83 (1.53 5.21)**
Residential density[a]	1.15 (0.79 1.66)[c]	1.02 (0.71 1.45)[c]	1.22 (0.93 1.61)[c]	1.42 (0.96 2.10)[c]	0.99 (0.68 1.44)[c]	1.18 (0.85 1.62)[c]
Connectivity between streets[a]	1.00 (0.72 1.39)[c]	0.71 (0.48 1.03)[c]	0.87 (0.63 1.20)[c]	0.78 (0.53 1.14)[c]	0.64 (0.41 1.01)[c]	0.75 (0.49 1.14)[c]
Blocks density[a]	1.29 (0.93 1.80)[c]	0.91 (0.64 1.31)[c]	0.96 (0.69 1.32)[c]	0.73 (0.50 1.08)[c]	0.94 (0.61 1.44)[c]	0.95 (0.66 1.37)[c]
Average size of the blocks[a]	1.04 (0.80 1.35)[c]	0.97 (0.59 1.58)[c]	1.02 (0.76 1.38)[c]	1.14 (0.78 1.65)	0.71 (0.44 1.17)	0.88 (0.59 1.32)
Walkability[a]	1.03 (0.89 1.20)[c]	0.88 (0.77 1.01)[c]	1.00 (0.88 1.14)[c]	0.88 (0.75 1.03)[c]	0.86 (0.72 1.02)[c]	0.95 (0.82 1.09)[c]

Low (0.5 km buffers) - High correlation between following variables: Residential density with blocks density (rho = 0.69) and walkability (rho = 0.79).
Blocks density with connectivity between streets (rho = 0.84), existence of park and squares (rho = 0.60) and walkability (0.88). Connectivity between streets with average size of the blocks (rho = 0.74) and walkability (rho = 0.93).
Low (1 km buffers) - High correlation between following variables: Residential density with connectivity between streets (rho = 0.72), blocks density (rho = 0.83) and walkability (rho = 0.83). Connectivity between streets with blocks density (rho = 0.88) and walkability (rho = 0.94). Blocks density with walkability (rho = 0.90).
Middle (0.5 km buffers) - High correlation between following variables: Land use mix with neighborhood recreation facilities (rho = 0.64); residential density with blocks density (rho = 0.66) and walkability (rho = 0.78). Blocks density with connectivity between streets (rho = 0.77) and walkability (0.82); connectivity between streets with average size of the blocks (rho = −0.77) and walkability (rho = 0.87). Average size of the blocks with walkability (rho = −0.61).
Middle (1 km buffers) - High correlation between following variables: Land use mix with neighborhood recreation facilities (rho = 0.64). Residential density with connectivity between streets (rho = 0.60), blocks density (rho = 0.76) and walkability (rho = 0.80). Connectivity between streets with blocks density (rho = 0.84) and walkability (rho = 0.92). Blocks density showed high correlation with walkability (rho = 0.90).
High (0.5 km buffers) - High correlation between following variables: Residential density with blocks density (rho = 0.67) and walkability (rho = 0.78); Blocks density with connectivity between streets (rho = 0.72) and walkability (rho = 0.80); connectivity between streets with average size of the blocks (rho = −0.77) and walkability (rho = 0.84).
High (1 km buffers) - High correlation between following variables: Residential density with blocks density (rho = 0.76) and walkability (rho = 0.76). Connectivity between streets with blocks density (rho = 0.76) and walkability (rho = 0.85). Blocks density with walkability (rho = 0.84).

[a] Standardized variables (transformed into z-scores).
[b] Adjusted for sex, age, socioeconomic status and class.
[c] Additionally adjusted for model 1[a], without the environmental variables that present high colinearity (rho ≥ 0.60).

Another aspect that was not included was for how long has the participant being living in that address or neighborhood, which could influence their perceptions. The lack of topographic characteristics, not using larger buffers sizes and information to compose original walkability index may also be worth to mention as a limitation since it may influence the results. Future studies should consider personal and social factors to understand the behavior of active commuting.

In conclusion, ACS was associated with land use mix, neighborhood recreation facilities, existence of parks, squares and residential density in Brazilian adolescents. The presence of a bicycle paths seems of particular relevance for ACS in all SES levels in both of the buffers studied. Although some environmental characteristics were important across all SES levels others were important in a specific SES level. These factors must be taken into consideration by policy makers when considering interventions aimed to increase this healthy behavior.

Ethical approval

The study was approved by the Ethics Committee of Research with Human Beings of the Federal University of Rio Grande do Sul, under number 1338.597.

Competing interests

None declared.

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