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Built environment and physical activity of adolescents: an approach with artificial neural networks

Ambiente construído e atividade física de adolescentes: uma abordagem com redes neurais artificiais

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ABSTRACT

The objective of this study was to analyze the association of the level of physical activity (PA) and body composition in relation to the amount and distance of built environments favorable to the practice of PA in relation to the homes of adolescents in the city of Lagoa do Carro/Pernambuco, Brazil. A total of 289 adolescents (153 boys; 10 to 18 years) participated in the study, duly enrolled in schools municipality. The self-administered Physical Activity Questionnaire for Children (PAQ-C) and Physical Activity Questionnaire for Adolescent (PAQ-A) was used to assess the PA level. The Geographic Information System was used to assess the built environments. Buffers of 100 to 500 meters were created from the center of the built environment. The Artificial Neural Network in the Feedforward method was used to assess the association and importance of built environment and body composition variables with PA level. The different distances from the built environment to the place of residence do not present statistical differences. It is noteworthy that the number of buffers up to 500 meters away was the variable that showed the greatest importance for the PA level, along with adolescents who live in places with greater exposure in terms of built environments, being considered more active. It was possible to conclude that the main determinants of the PA level of adolescents were the amount of buffers at 500 meters, sex and the distance to the built environment. However, the variables, housing area, body mass and amounts of buffers at 100 meters were the ones with the lowest power of influence.

Keywords: Artificial neural network; Adolescents; Georeferencing.

RESUMO

O objetivo deste estudo foi analisar a associação do nível de atividade física (AF) e composição corporal em relação à quantidade e distância de ambientes construídos favoráveis à prática da AF em relação ao domicílio de adolescentes da cidade de Lagoa do Carro/Pernambuco, Brasil. Participaram do estudo 289 adolescentes (153 meninos; 10 a 18 anos), devidamente matriculados nas escolas do município. O Physical Activity Questionnaire for Children (PAQ-C) e Physical Activity Questionnaire for Adolescent (PAQ-A) autoaplicável foram utilizados para avaliar o nível de AF. O Sistema de Informação Geográfico foi utilizado para avaliação dos ambientes construídos. Foram criados Buffers de 100 a 500 metros de raio a partir do centro do ambiente construído. A Rede Neural Artificial no método de Feedforward foi utilizada para analisar a associação e a importância das variáveis do ambiente construído e composição corporal com o nível de AF. Não foram observadas diferenças estatisticamente significativas entre o nível de AF e as distâncias do ambiente construído. Ressalta-se que a quantidade de buffers até 500 metros de distância, foi a variável que apresentou maior importância para o nível de AF, juntamente com os adolescentes que residem em locais com maior exposição em quantidade de ambientes construídos, sendo considerados mais ativos. Os principais determinantes do nível da AF dos adolescentes foram à quantidade de buffers a 500 metros, o sexo e a distância para o ambiente construído. Em contrapartida, as variáveis, zona de moradia, massa corporal e quantidades de buffers a 100 metros foram as que apresentaram um menor poder de influência.

Palavras-chave: *Rede neural artificial; Adolecentes; Georreferenciamento.*

Introduction

Adolescence is a transitional phase between childhood and adulthood, characterized by changes in the speed of physical growth and motor performance[1], as well as significant alterations in the psychological domain, especially in personal and social behaviors[2,3]. During this stage of life, it is considered that all individuals are healthy, however, the incidence of chronic non-communicable diseases is increasing in the adolescent population. This fact can be understood by the lack of healthy eating habits and the reduction in physical activity levels (PA)[4].

Ecological models applied to the field of PA Epidemiology suggest the existence of multiple influences of the physical, natural, and built environment, on the PA levels of children and adolescents[5]. For example, Carlson et al.[6], observed in adolescents (n = 690; 12 to 16 years) that intersection density and neighborhood walkability were positively related to active commuting (i.e., walking and cycling).

In Brazil, specifically in the northeast region, there are few studies that consistently show direct or indirect relationships between characteristics of the built environment and different levels of PA. Notwithstanding this fact, a study carried out with adolescents and adults (n = 2046; 16 to 55 years of age), residents of the city of Recife, Pernambuco, showed that the lack of sidewalks and low access to recreational facilities were associated with a lower probability of performing 150 minutes or more per week of leisure-time PA[7].

In countries in transition, especially in cities with a low human development index, adolescents are often exposed to environments marked by personal and family insecurity, crime, and traffic accidents[8], as well as reduced access to public squares, parks, and sports facilities [9], which may result in decreased levels of practice of various physical activities[10]. In contrast, the accessibility, availability, and attractiveness of facilities built for the practice of PA tend to significantly increase the chances of adolescents becoming more active[11].

The Geographic Information System (GIS) methodology has been particularly relevant in describing and understanding the active travel routes of adolescents on their journeys from home to school[12]. In the GIS-based observation and measurement system, it is common to determine an area around each subject's residence, called a buffer, from which it is possible to construct a varied set of indicators (for example, walkability) in relation to this area.

Furthermore, the use of computational techniques to identify factors related to PA is relevant in the decision-making process regarding planning and preventive interventions in public health[13]. The choice of an artificial neural network (ANN) was based on the ability of this method to identify patterns from systematic relationships between variables, in order to obtain information that is considered useful for linear prediction models[14].

In this sense, the current study seeks to answer the following question: Can distances from built environments be considered indicators of the PA level in adolescents? Therefore, the objectives of this study follow from this: (1) analyze the level of PA based on the quantity and distance of existing built environments, in relation to the home and (2) examine the existence of differences in the body composition of adolescents stratified by the PA level. Our hypothesis was that both the distance and the number of built environments in relation to the place of residence can influence the PA level of adolescents and their body composition.

Methods

This study is a cross-sectional and quantitative study, conducted in the city of Lagoa do Carro, located in the northeast region, Mata Norte area of the state of Pernambuco, Brazil. The city has a population of 18,071 inhabitants, occupying an area corresponding to 69,870 km[2,15]. The population density is 259.4 inhabitants per km^2 in the municipality. The project was approved by the Human Research Ethics Committee of the University of Pernambuco (No. 2,520,417). All adolescents and guardians signed the consent and assent form, attesting to their voluntary participation in the research.

The data for the development of this study come from a research project entitled: "Healthy Life in Lagoa do Carro: a family-based study" designed to describe and interpret the relational framework of family and environmental factors (school and built), in the variation in physical growth, body composition, physical fitness, motor coordination, PA, and metabolic risk among children and adolescents in Lagoa do Carro. This project also has an extension with nuclear families focused on the top-down approach of Genetic Epidemiology[16].

The present study included 289 adolescents (153 boys), enrolled in 17 municipal schools, from the sixth to ninth grade of secondary school, aged between 10 and 18 years. The exclusion criteria adopted were adolescents who presented any neurological deficit and/or musculoskeletal problems that could limit the performance of the assessments. In addition, pregnant teenagers and/or students who did not have a residential address listed on their school registration form or in the Brazilian government's direct income transfer program, which is aimed at families in poverty (Bolsa Família).

Anthropometry and body composition

Height (cm), sitting height (cm), and body mass (kg) were obtained using standardized methods[17]. To measure height, a portable stadiometer (Sanny, São Paulo, Brazil) was used, with an accuracy of 0.1 cm, which was also used to measure sitting height, together with a wooden bench of known height (50 cm). Body mass was measured with a portable scale (G Tech, São Paulo, Brazil), with an accuracy of 0.1 kg. The body mass and height values were used to calculate the body mass index (BMI): [BMI=mass (kg)/height^2 (m)]. The BMI classification considered the Z-Score distribution, using *WHO Anthro Plus* software (version 1.0.4) considering the adolescent's sex, date of birth, and age at the time of assessment[18].

The anthropometric method was used to estimate body composition in two compartments – fat mass (FM) and lean body mass (LBM). For this purpose, measurements of the thickness of the triceps and subscapular skinfolds were obtained using an adipometer (Lange, Santa Cruz, United States of America), with a constant pressure of 10 g·mm^{-2} and precision of 1 mm. Measurements were performed in triplicate and the median value was adopted. FM was calculated from the relationship between body weight and body fat percentage and expressed in kilograms. LBM was calculated from the difference between body weight and fat mass and expressed in kilograms[17].

Waist and hip circumference measurements were obtained in duplicate, using a non-stretchable metal tape measure (Cescorf, Porto Alegre, Brazil) with an accuracy of 0.1 cm, according to previously described conventional techniques[19]. The average value between the two measurements was used as a reference.

Biological maturation

The assessment of biological maturity was performed using the method described by Mirwald, Baxter-Jones[20], which uses equations specific to each biological sex based on information on age, height, sitting height, and lower limb length to predict the distance, in years, that each participant is from reaching peak height velocity (PHV). This distance is called the maturational offset. A positive value of maturational offset represents the number of years the participant is beyond the PHV, while a negative value represents the number of years the participant is before the PHV.

Built environment

Information regarding the public spaces of built environments, as well as public sports facilities and equipment, was obtained from the city's Department of Architecture and Urbanism, considering the following indicators: (a) sports complexes (area with sports equipment, including sports fields and courts, swimming pools, and gyms); (b) public parks (natural or semi-natural green areas used for recreational activities); (c) sports fields and courts; and (d) *playgrounds* (area designated for children). Thus, based on these indicators, four public facilities were located in the municipality of Lagoa do Carro/Pernambuco, namely, a soccer field, a square with several facilities, and two multi-sports courts, one with a roof and the other open-air (i.e., without a roof). These maps can be accessed in Supplementary Material.

Data from the city's census sectors were collected from the website of the Brazilian Institute of Geography and Statistics (IBGE) to demarcate rural and urban areas. After collecting the census sector, the existing built environments were georeferenced and the adolescents' homes were located manually, point by point. Due to the size of the city, five crow-fly type buffers were established [21] for each built environment (i.e., 100, 200, 300, 400, and 500 meters) so that it was possible to inventory the number of adolescents who lived within the described radius using the *Google Earth Pro* program. It is worth noting that the count of adolescents in relation to the buffers was given continuously, that is, the adolescent who was in the 100 buffer was also in the larger buffers. Finally, the Qgis 3.4.11 program was used to create maps of the municipality, with the aim of helping to interpret the distributions of built environments and the locations of the adolescents' homes.

Physical activity

To describe the PA levels, the *Physical Activity Questionnaire for Children* (PAQ-C) and *Physical Activity Questionnaire for Adolescents* (PAQ-A) questionnaires were used, translated into Portuguese and cross-culturally adapted for Brazilian adolescents. Both questionnaires allow scores equivalent to the total PA level, computed through the arithmetic mean of the scores attributed to each question[22]. In the present study, the level of PA was categorized into two groups according to the points achieved, being: (0): low PA (1.00 to 2.74 points) and (1): moderate to vigorous physical PA (> 2.75 points)[23] .

Statistical analysis

Initially, an exploratory analysis of the data was carried out to check for possible information input errors (outliers), as well as to test the hypothesis of normality and homogeneity through the Kolmogorov-Smirnov and Levene tests, respectively. The median and interquartile range were used to present continuous variables, while categorical data were presented using absolute and relative frequencies. Differences between groups (i.e., low PA and moderate to vigorous PA) were tested using the Mann-Whitney *U test for independent samples and the Chi-Square test* (χ^2) for categorical variables.

Procedure adopted for the artificial neural network (ANN)

The identification of variables that could influence the level of PA of adolescents was carried out through ANN analysis. Before starting the execution of the ANN, it was necessary to perform the data normalization procedure for the range between 0 and 1. This type of procedure is necessary because the data presented to the ANN are under the domain of the activation function used (categorical and numerical). The ANN used was built based on the Feedforward method in order to verify more complex associations and the importance of independent variables for dependent variables. Initially, a division of 70% for training and 30% for testing was used. The architecture of the ANN used in the experiments was then fixed in the structure of 1 input layer containing 14 classes, 1 layer of hidden neurons (empirically defined) containing 7 classes, and 1 neuron in the output layer containing 2 classes. In this way, the ANN used is 14 - 7 – 1. The input and output variables in the ANN are described in Table 1. The neural network performance was then determined by sensitivity, specificity, and the area under the receiver operating characteristic (ROC) curve. All procedures were performed using IBM *SPSS Statistics for Windows*, version 22.0 (IBM Corp., Armonk, N.Y., USA). The significance level was set at $p<0.05$.

Results

Table 2 presents the descriptive characteristics of the adolescents, according to the level of PA. Adolescents with low PA levels presented higher mean values in all anthropometric variables and in LBM ($p<0.001$). In addition, they were slightly more advanced from a maturational point of view, compared to their peers in the moderate to vigorous PA group. In relation to the sum of adiposity folds, fat percentage, and fat mass, no differences were observed ($p>0.05$).

Information regarding sex, residential area, distance characteristics of built environments in relation to the adolescents' residence, and the number of buffers according to the radii established according to the adolescents' PA level are presented in Table 3. The proportion of female adolescents in the moderate to vigorous PA category was higher than their male peers ($p<0.05$). No significant differences were observed between the groups in relation to the location of the residence (residential area and number of buffers), or between the distances observed in relation to the residences and the built environments ($p>0.05$).

Artificial neural network (ANN) construction and performance

To construct the ANN, 14 variables related to sex, body composition, maturational stage, and built environments were included. These variables were then inserted into the ANN, which had the function of establishing the relationship between these variables and two classes in the output layer referring to the groups of adolescents with low and moderate/vigorous PA levels, as previously described in Table 1.

The best ANN prediction model was obtained through the structure of 14 classes in the input layer, and 7 classes of neurons in the hidden layer, for the 2 classes referring to the output, to predict the PA level of adolescents (supplementary file). The ROC curve analysis indicated that the area under the curve presented good reliability (0.72; $p<0.05$) in the PA level classification model. Table 4 shows that for the group used for training (learning) the network, the prediction of the accuracy of the PA level was 60.1%, while the real values presented a prevalence of 68.4%. Furthermore, the training set presented sensitivity of 70.5%, specificity of 62.5%, and accuracy of 67.9%. In the group used for testing (validation) the network, the prediction of the PA level estimate was 55.2%, while the real values presented a prevalence of 70.5%, sensitivity of 65.0%, specificity of 68.0%, and accuracy of 65.8%. These results indicate that the ANN was able to demonstrate a good capacity to simulate both outputs when identifying differences in PA levels, using only variables associated with body composition, maturational stage, and the built environment.

From the ANN analysis, the qualitative significance (normalized importance) of the input variables on the predicted values of low and moderate/vigorous PA are presented in Table 5. It can be observed that the number of buffers 500 meters away from the built environment and sex were the variables that presented

Table 1 – Input and output variables for artificial neural network models

Levels	Variables	Categories	Description
Output	Physical activity level	Low Moderate/vigorous	Categorical
Inputs	Sex	Female Male	Categorical
	Nutritional status	Low weight Normal weight Excess weight	Categorical
	Maturational stage	Pubescent Post-pubescent	Categorical
	Living area	Rural Urban	Categorical
	Number of buffers at 100 meters†	0 1 2	Categorical
	Number of buffers at 200 meters†	0 1 2	Categorical
	Number of buffers at 300 meters†	0 1 2 3	Categorical
	Number of buffers at 400 meters†	0 1 2 3	Categorical
	Number of buffers at 500 meters†	0 1 2 3 4	Categorical
	Distance from the built environment to the residence	100 200 300 400 500 More than 500 meters	Continuous
	Body mass (kg)	-	Numerical
	Waist circumference (cm)	-	Numerical
	Fat mass (kg)	-	Numerical
	Lean body mass (kg)	-	Numerical

† Number of buffers relative to the place of residence.

the greatest relative contribution to the level of PA. In addition, it was found that sex also had an important relative contribution to the level of PA. On the other hand, the indicators of body mass and the area of residence (rural or urban) demonstrated less relative importance for the model.

Table 2 – Median and interquartile range of anthropometric variables, maturational stage, and body composition.

	Level of physical activity		
	Low (n = 170)	Moderate to vigorous (n = 119)	p-value
Age (years)	11.0 (1.3)	11.0 (1.2)	0.45
Height (cm)	147.2 (10.9)	144.0 (11.9)	<0.01*
Body mass (kg)	39.6 (15.5)	35.5 (10.7)	<0.01*
Body mass index (kg/m²)	18.2 (5.4)	16.9 (3.5)	<0.01
Waist circumference (cm)	63.7 (11.7)	60.3 (7.4)	<0.01*
Hip circumference (cm)	78.9 (14.0)	75.0 (10.6)	<0.01*
Maturational offset (years)	-1.3 (1.8)	-1.9 (1.2)	<0.01*
Σ of two skinfolds (mm)	23.0 (15.8)	21.0 (12.0)	0.19
Body fat (%)	24.5 (10.5)	24.5 (8.9)	0.91
Fat mass (kg)	9.4 (6.6)	8.8 (4.6)	0.07
Lean body mass (kg)	28.6 (10.0)	25.7 (7.3)	<0.01*

Mann-Whitney U test *p-value <0.01

Table 3 – Absolute and relative values of the characteristics of distance and location of residence of adolescents according to the level of physical activity.

	Level of physical activity			
	n	Low level (n = 170) %	Moderate to vigorous level (n = 119) %	p-value
Sex				
Male	153	66.9	33.1	<0.05
Female	136	51.6	48.4	
Residential area				
Rural	40	55.0	44.0	0.597
Urban	249	59.4	40.6	
Number of buffers at 100 meters				
0	221	58.4	41.6	0.691
1	67	59.7	40.3	
2	1	100.0	0.0	
Number of buffers at 200 meters				
0	139	58.3	41.7	0.983
1	76	59.2	40.8	
2	74	59.5	40.5	
Number of buffers at 300 meters				
0	111	59.5	40.5	0.954
1	31	58.1	41.9	
2	78	56.4	43.6	
3	69	60.9	39.1	
Number of buffers at 400 meters				
0	108	59.3	40.7	0.910
1	16	62.5	37.5	
2	86	55.8	44.2	
3	79	60.8	38.2	
Number of buffers at 500 meters				
0	105	59.0	41.0	0.399
1	14	64.3	35.7	
2	8	62.5	37.5	
3	154	59.7	40.3	
4	8	25.0	75.0	
Distance from the built environment				
100 meters	68	63.2	36.8	0.145
200 meters	82	67.1	32.9	
300 meters	27	63.0	37.0	
400 meters	3	66.7	33.3	
500 meters	3	66.7	33.3	
More than 500 meters	106	48.1	51.9	

Table 4 – Neural network performance.

Area under the ROC curve	0.72
p-value	<0.05
Training (n = 203)	%
Sensitivity	70.5
Specificity	62.5
Real prevalence	68.4
Estimated prevalence	60.1
Accuracy	67.9
Test (n = 85)	
Sensitivity	65.0
Specificity	68.0
Real prevalence	70.5
Estimated prevalence	55.2
Accuracy	65.8

Table 5 – Indicators of physical activity level.

	Importance	Normalized importance %
Number of buffers at 500 meters	0.116	100.0
Sex	0.113	97.6
Distance from the built environment	0.101	87.0
Number of buffers at 300 meters	0.097	83.5
Number of buffers at 200 meters	0.084	72.0
Fat mass	0.068	58.4
Waist circumference	0.066	56.6
Lean body mass	0.066	56.5
Number of buffers at 400 meters	0.061	53.3
Body mass index	0.059	51.2
Maturational offset	0.056	48.2
Number of buffers at 100 meters	0.043	37.4
Body mass	0.040	34.2
Residential area	0.030	25.6

Discussion

In the current study, it was observed that the number of buffers at 500 meters presented the greatest contribution of the built environment (100%) to the level of adolescent PA, in the context of the City of Lagoa Carro/Pernambuco. According to studies carried out on built environments, there are multiple influences of the physical environment on PA (i.e., existence of squares, parks, and courts)[5]. However, evidence on the relationship between the built environment and PA is less consistent among adolescents than among adults[24].

A review study conducted by Brownson et al.[24], reported consistent relationships between some characteristics of the built environment (i.e., availability of recreational facilities and mixed land use) and adolescents' PA, but with inconsistent associations with other characteristics of the environment (i.e., street connectivity and walking facilities).

In the current study, the ANN showed good reliability in categorizing the PA level of adolescents, both for those considered to have moderate to vigorous PA levels and those with low levels. According to the ANN, the variables number of buffers within 500 meters (100%), sex (97.6%), and distance from the built environment to the place of residence (87.0%) were the three variables that presented the greatest importance in categorizing the level of PA of adolescents.

This fact reinforces the possibility of using input variables (number of buffers within 500 meters and distance to the built environment) to categorize the level of PA, characterizing these variables as indicators that can assist in plans aimed at increasing the level of PA of adolescents; the development of effective public health interventions being essential to produce long-term health benefits, even in small cities.

When considering the number of buffers within 500 meters, it was observed that the more buffers the teenagers are inserted in, the more active they tend to be, rising from 35.7% for those residing within 1 (one) buffer to 75.0% among those residing in 4 (four) buffers. According to Oreskovic et al.[11], the more open space options (parks and squares) within a 400-meter radius of adolescents' homes, the lower the probability of overweight and obesity. Similarly, the authors report that the greater the number of fast food restaurants within a 400-meter radius, the greater the probability of overweight and obesity among adolescents living in the region. This fact in itself has a high informative potential, since, when thinking about city and neighborhood planning, the distances between housing sites and the built environment need to be considered.

In the current study, it was clearly observed that considering the distance between the residence and the built environment, adolescents living more than 500 meters from the built environment are more active than their peers who live closer to the built environment. In this context, Grieco et al.[25], highlight that people living in places further away from urban centers tend to have less access to public transport, which leads residents of these regions to travel long distances to use public transport or to urban centers, which consequently increases the use of active transport, such as walking and cycling.

Furthermore, the association between recreational facilities and moderate and vigorous PA is known to be consistent with previous studies conducted among adolescents[10, 26]. The positive association between residential density, walkability, and moderate and vigorous PA among adolescents is also consistent with studies from New Zealand[27] and the United States of America[6]. When examining the variables of least importance, according to ANN, it was observed that residential area (25.6%), body mass (34.2%), and number of buffers within 100 meters (37.4%) were the variables that stood out. Although these variables express a lower explanatory power, when analyzing the residential area, it is observed that regardless of whether they live in an urban or rural area, most adolescents have a low level of PA. In this context, in a study carried out in India, the authors reported that 50.0% of the rural population and 65.0% of the urban population were classified as having a low level of PA, with a greater predominance of children and adolescents. Furthermore, problems of lack of PA and obesity are no longer exclusive to people living in urban areas, which is often justified by the geography and inadequate infrastructure in rural areas. Thus, in the current study, it is possible that the territorial extension of the city itself is considered an information bias, since as the buffer is expanded the possibility of joining urban and rural areas becomes evident, mainly because Lagoa do Carro is a small city[28,29].

The ANN indicates that the number of buffers within 100 meters does not play an important role in the level of PA of adolescents. This finding can be explained, at least in part, by the fact that, in addition to living close to built environments, the aesthetics and quality of sports facilities influence the practice of PA. In this context, characteristics such as: environmental attributes, accessibility to parks, and security levels are factors that are associated and highly prevalent with the practice of PA in built environments[30]. In addition, the characteristics of the city studied must be considered; at a distance of 100 meters, approximately 76.4% (221 adolescents) of the sample do not have any built environment, a fact that may reduce the importance of this distance in favoring the level of PA of adolescents.

The current study has limitations that need to be considered when interpreting the results: a) The study sample is not representative beyond the adolescents from the city of Lagoa do Carro/Pernambuco, Brazil, therefore, there is no possibility of extrapolating the results, since the study was not designed to represent the entire Brazilian population; and b) PA was estimated using a questionnaire, which has known limitations, especially at younger ages, however, financial and logistical aspects limited our choice to a questionnaire. Despite these limitations, this study has strengths. First, we used consistent methods and performed quality control of data collection in the evaluation. In addition, the use of the ANN model was efficient in identifying classifiers of PA level in adolescents from a small, poor city in the Northeast region of Brazil.

Finally, the main determinants of the PA level of adolescents living in the city of Lagoa do Carro/Pernambuco were the number of buffers within 500 meters, sex, and distance from the built environment. On the other hand, the variables housing area, body mass, and quantity of buffers at 100 meters presented the least power of influence. These findings imply that multi-level interventions targeting both the built environment and social support may be needed to foster active behaviors among adolescents outside of school hours, even in small towns.

Conflict of interest

The authors declare no conflict of interest.

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Authors' contributions

Correia Júnior MGA: Conceptualization; Methodology; Data analysis; Research; Data presentation design; Writing of the original manuscript; Writing-review & editing; Approval of the final version of the manuscript. Prazeres TMP: Software development, implementation and testing; Provision of tools; Data curation; Supervision; Project administration; Writing of the original manuscript; Writing-review & editing; Approval of the final version of the manuscript. Henrique RS: Software development, implementation and testing; Data and experiment validation; Tool provision; Data curation; Supervision; Project administration; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Alarcon J: Research; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Nobre IG: Data analysis; Research; Data presentation design; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Pinto BCP: Methodology; Software development, implementation and testing; Data analysis; Research; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Arruda GA: Methodology; Data analysis; Data presentation design; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Maia DEF: Research; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Sá LACM: Methodology; Software development, implementation and testing; Data analysis; Research; Provision of tools; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript. Santos MAM: Conceptualization; Methodology; Data and experiment validation; Provision of tools; Supervision; Data presentation design; Receipt of funding; Writing of the original manuscript; Writing - review and editing; Approval of the final version of the manuscript.

Declaration regarding the use of artificial intelligence tools in the article writing process

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Supplementar material

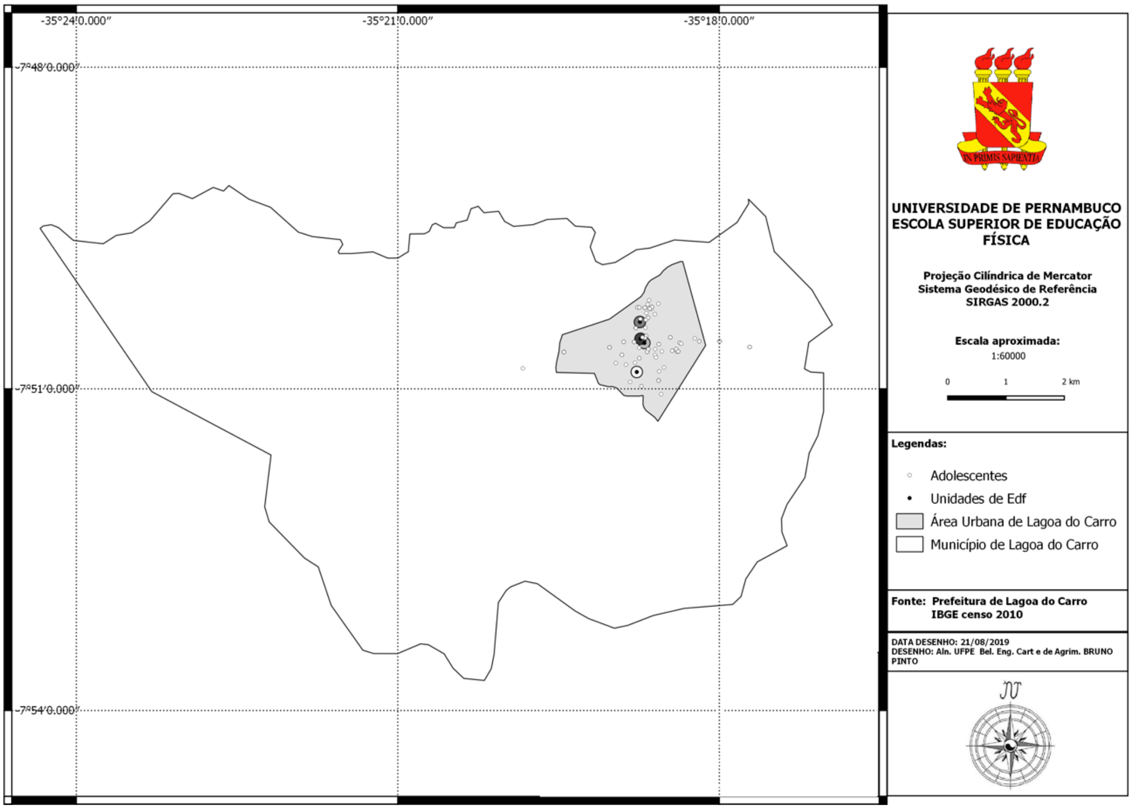

Figure 1 – 100 meter buffers.

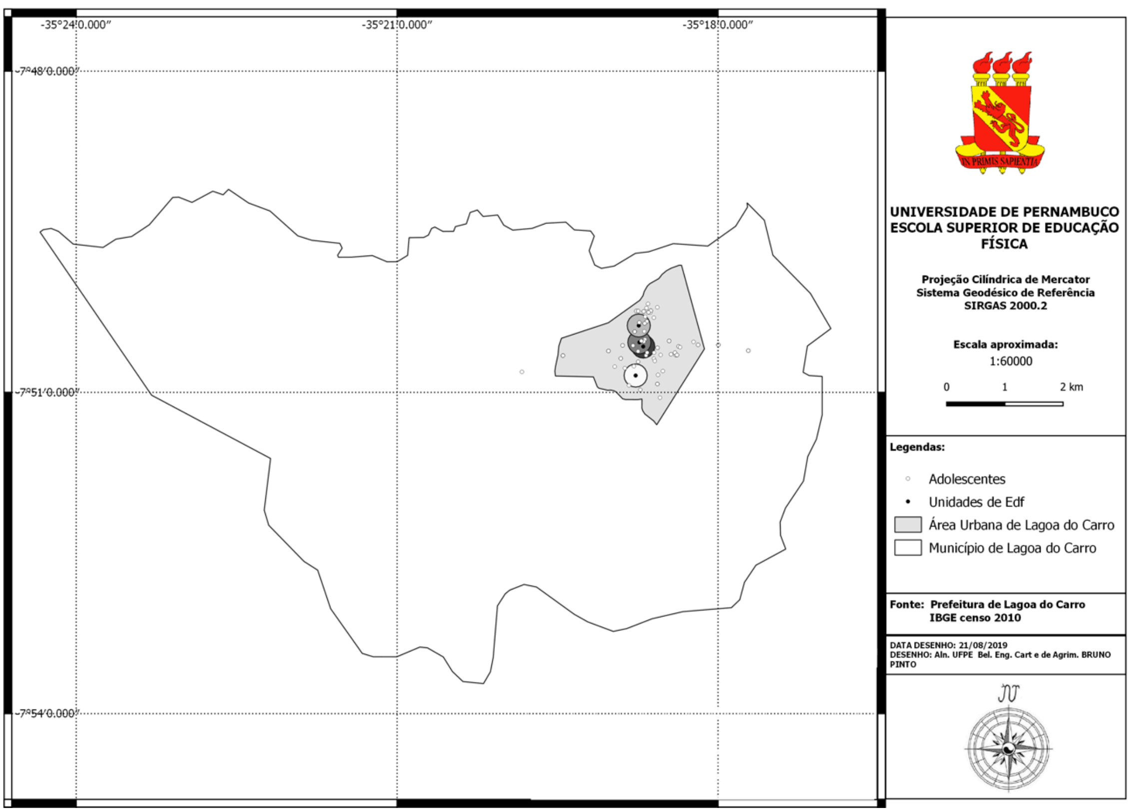

Figure 2 – 200 meter buffers.

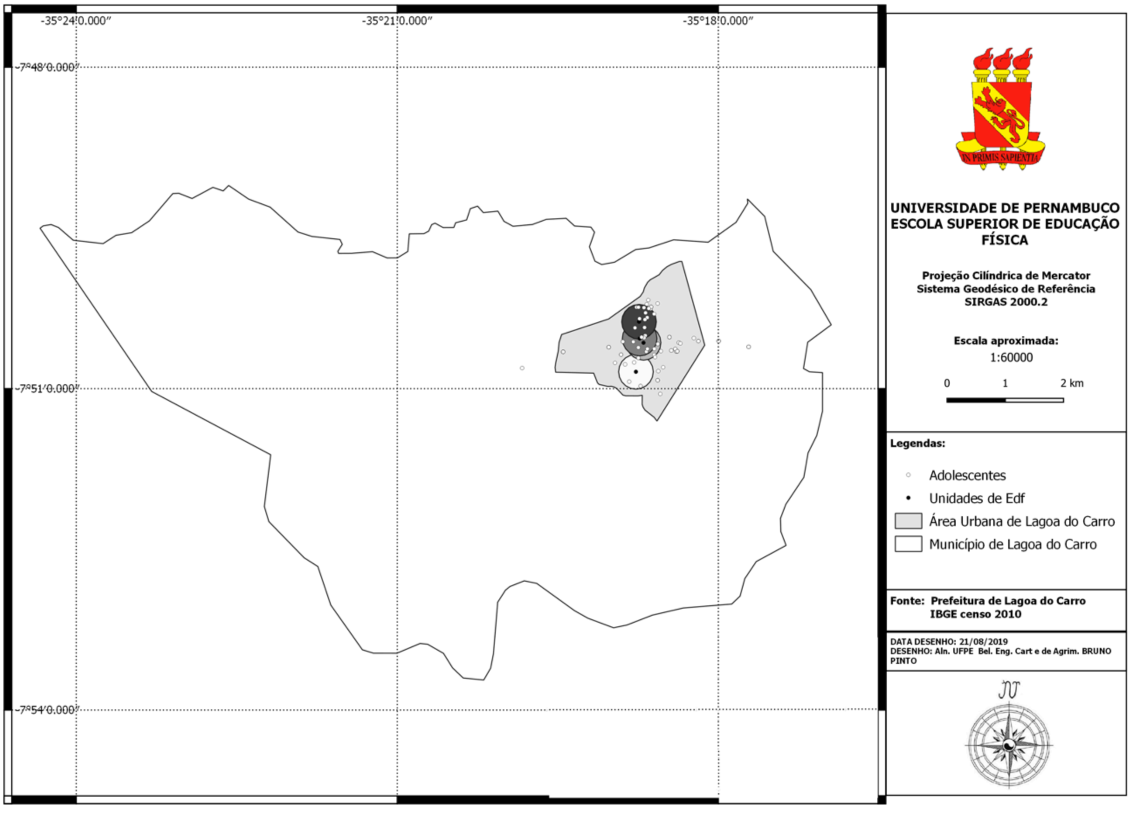

Figure 3 – 300 meter buffers.

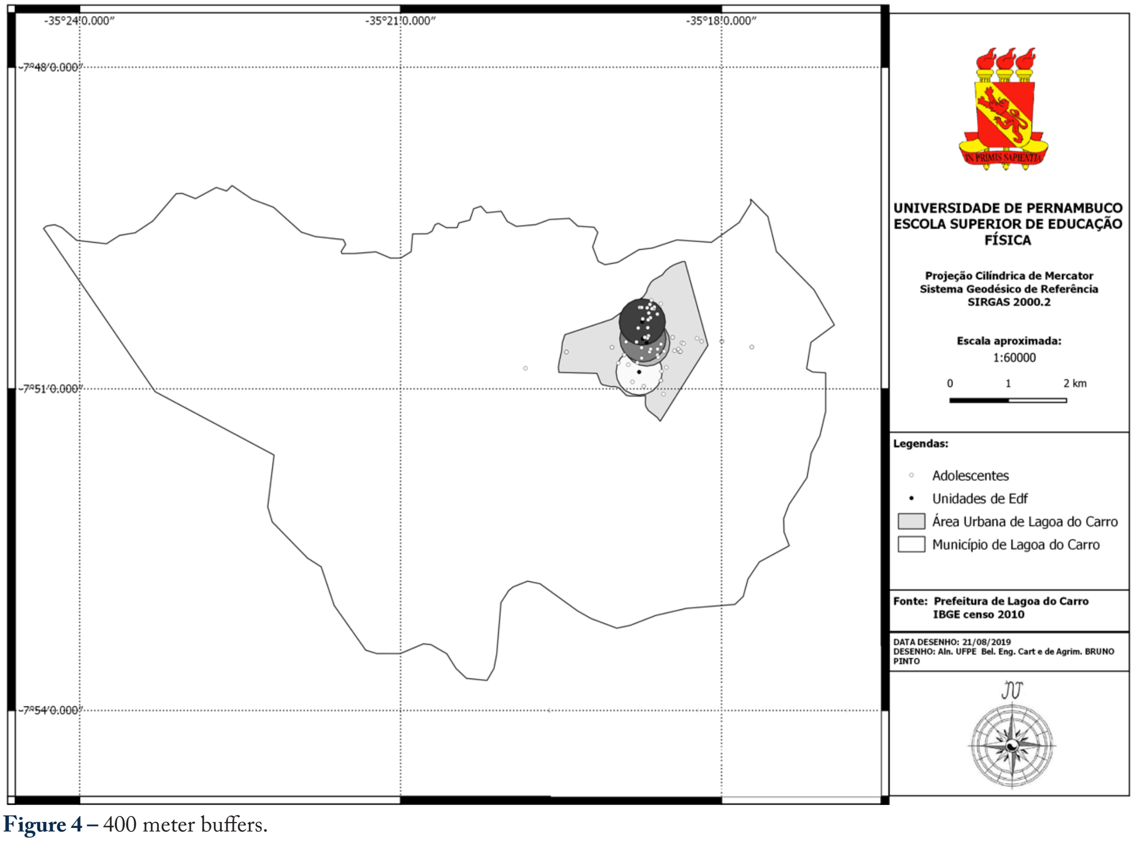

Figure 4 – 400 meter buffers.

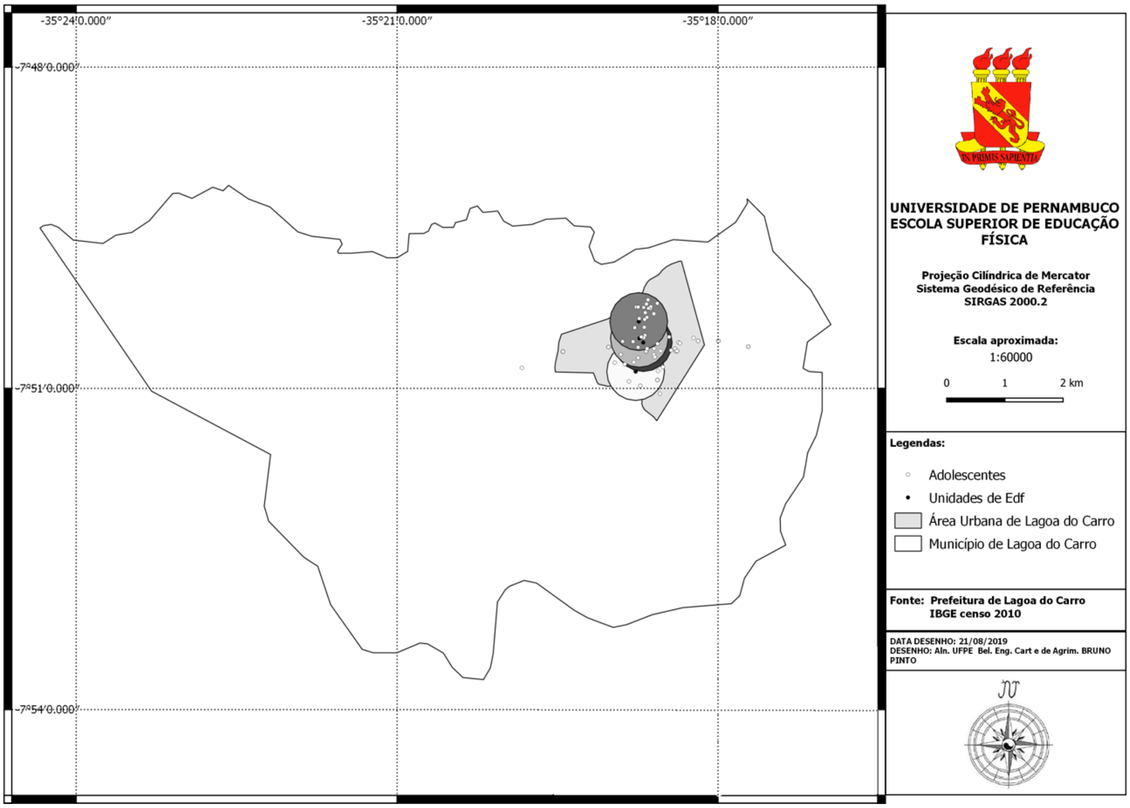

Figure 5 – 500 meter buffers.