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Walking for transportation and built environment in Sao Paulo city, Brazil

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ABSTRACT

Objective: To describe the profile of adults who walk for transportation in Sao Paulo city, and to explore the built environment features that are associated with transport walking.
Material and methods: This study was a cross-sectional analysis of the Sao Paulo Health Survey dataset (n = 3145 people aged 18 years or older) that measured walking for transportation in a usual week by questionnaire. Residential addresses were geocoded and types and mix of destinations were assessed in 500 m and 1,000 m buffers. We conducted Poisson regression to calculate the prevalence ratio and we used multilevel models to examine relationships between the built environment and walking for transportation.
Results: People with higher levels of education and who were not obese were significantly more likely to walk for transportation. The cars or motorcycle ownership in families and aged 60 years old or more were significantly less likely to walk for transportation. After adjustment by social, demographic, and environmental variables, the main result showed that the highest tertiles of the mix of destinations within 500 m increased the likelihood of walking for transportation (OR = 1.40 CI95%1.01–1.93). The presence of public transportation stations within 1,000 m was significantly associated with walking for transportation for 150 min or more per week (OR = 1.65 CI95%1.02–2.68). The presence of different types of destinations such as primary health care units, train or subway stations, bakeries, and the high density of supermarkets within 1,000 m were significantly associated with some walking for transportation. The presence of bakeries in 500 m was strongly associated with some walking for transportation.
Conclusions: The mix of destinations within 500 m and some types of destinations within 1,000 m are important to promote walking trips in adults living in a megalopolis like Sao Paulo. These results can foster discussion of healthy cities in Latin American countries.

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R E S U M O

Objetivo: Descrever o perfil de adultos que caminham como transporte na cidade de São Paulo e verificar as variáveis de ambiente construído que estão associadas com caminhada como forma de transporte.
Material e Métodos: Este foi um estudo transversal que utilizou dados do Inquérito de Saúde de São Paulo (n = 3145 pessoas com 18 anos ou mais de idade) que avaliou caminhada como forma de transporte em uma semana usual por questionário. Os endereços residenciais foram geocodificados e os tipos e a mistura de destinos foram avaliados em raios de 500 m e de 1.000 m. Realizou-se regressão de Poisson para calcular as razões de prevalência e modelos multiníveis para verificar as relações entre o ambiente construído e a caminhada como forma de transporte.
Resultados: Pessoas com altos níveis de educação e que não eram obesas tiveram maiores razões de prevalência para caminhar como transporte. As pessoas com posse de carros ou motocicletas pelas famílias e com idade acima de 60 anos tiveram menores razões de prevalência para caminhar como forma de transporte. Depois do ajuste por variáveis sociais, demográficas e ambientais, o principal resultado mostrou que altos tercis de mistura de destinos dentro de 500 m aumentaram as chances de caminhada como forma de transporte (OR = 1,40 IC95%1,01-1,93). A presença de estações de transporte público dentro de 1,000 m foi significativamente associada com caminhada como transporte por 150 minutos ou mais por semana (OR = 1,65 IC95%1,02--2,68). A presença de diferentes tipos de destinos como unidades básicas de saúde, estações de trem ou metrô, padarias e altas densidades de supermercados dentro de 1.000 m foram significativamente associadas com caminhada como forma de transporte. A presença de padarias dentro de 500 m foi fortemente associada com caminhada como forma de transporte.
Conclusão: A mistura de destinos dentro de 500 m e alguns tipos de destinos dentro de 1.000 m são importantes para promover viagens de caminhadas em adultos em uma megalópole como São Paulo. Estes resultados podem fomentar a discussão sobre cidades saudáveis em países da América Latina.

R E S U M E N

Objetivo: Describir el perfil de adultos que caminan como forma de transporte en la ciudad de São Paulo y verificar las variables de ambiente construido que están asociadas a la caminata como forma de transporte.
Material y Métodos: Este fue un estudio transversal que utilizó datos de la investigación de Salud de São Paulo (n = 3.145 personas con 18 años o más de edad) que evaluó caminata como forma de transporte en una semana usual por cuestionario. Las direcciones residenciales fueron geocodificadas. Los tipos y la mezcla de destinos fueron evaluados en radios de 500 m y 1.000 m. Se realizó regresión de Poisson para calcular las razones de prevalencia y modelos multinivel para verificar las relaciones entre el ambiente construido y la caminata como forma de transporte.
Resultados: Personas con altos niveles de educación y que no eran obesas tuvieron mayores razones de prevalencia de caminata como transporte. Las personas que poseen automóviles o motocicletas por las familias y con edad superior a 60 años tuvieron menores razones de prevalencia de caminata como forma de transporte. Después del ajuste por variables sociales, demográficas y ambientales, el principal resultado mostró que los terciles más altos de mezcla de destinos dentro de 500 m hicieron más probable la caminata como forma de transporte (OR = 1,40 IC95%1,01-1,93). La presencia de estaciones de transporte público dentro de 1.000 m fue significativamente asociada a la caminata como transporte por 150 minutos o más por semana (OR = 1,65 IC95%1,02-2,68). La presencia de diferentes tipos de destinos como unidades básicas de salud, estaciones de tren o metro, panaderías y altas densidades de supermercados dentro de 1.000 m fueron significativamente asociadas a la caminata como forma de transporte. La presencia de panaderías dentro de 500 m fue fuertemente asociada a la caminata como forma de transporte.
Conclusión: La mezcla de destinos dentro de 500 m y algunos tipos de destinos dentro de 1.000 m son importantes para promover desplazamientos por caminatas en adultos en una megalópolis como São Paulo. Estos resultados pueden fomentar la discusión sobre ciudades saludables en países de América Latina.

1. Introduction

Walking is an important physical activity because it is an integral part of life and is a fundamental form of transportation (Roberts, 1998; Stamatakis et al., 2018a). Many epidemiological studies have shown the health benefits of walking, which include a decrease in all-cause mortality, prevention of cardiovascular disease and improvements in mental health (Boone-Heinonen et al., 2009; Kelly et al., 2018; Mueller et al., 2015; Stamatakis et al., 2018b). Besides being used for transport purposes, walking is often used in physical activity promotion programs because it is accessible for all age groups and can be practiced in leisure time (Bassett et al., 2008; Foster et al., 2018). Consequently, for people living in big cities, walking for transportation is also associated with other co-benefits, such as decreased air pollution and increased social capital (de Nazelle et al., 2011; Woodcock et al., 2007).

The prevalence of walking for transportation and active transport use has changed differently for countries in North and South America. Trend analysis in the United States of America shows that the number of people who engaged in any transportation walking increased from 28.4% in 2005 to 31.7% in 2015 (Ussery et al., 2018). In a study with adults from Colombia, the number of people walking 150 min or more per week increased between 2005 and 2010 (from 24.3% to 31.2% for females and 24.1% to 37.4% for males) (González et al., 2014). In Brazil however, active transportation - including the use of bicycle and walking – amongst adults from all state capitals have been shown to have decreased between 2006 and 2012 (Mielke et al., 2014).

Walking is a multifactorial behavior and the built environment is an important determinant (Ewing and Cervero, 2001). Studies show that factors such as distance to non-residential destinations, land use mix, population density, employment density, aesthetics, pedestrian infrastructure, network connectivity, safety, the availability of parks or open spaces, transportation stations, coffee-shops, small food stores, and supermarkets are associated with walking for transportation and walking trips (Bentley et al., 2018; Gunn et al., 2017; Kamruzzama et al., 2014; King et al., 2015; Knuiman et al., 2014; Rachele et al., 2018; Saelens and Handy, 2008; Zwald et al., 2014). In addition, the presence and accessibility of services is part of urban design that is important for walking trips (Ewing and Cervero, 2001). However, most of the studies reviewed were conducted either in European countries, the United States of America, or in Australia.

Few studies have explored the built environment influences on walking trips in Latin American cities. We found studies in Brazil and in Colombia (Hino et al., 2014; Lemoine et al., 2016). A study conducted on adults from Curitiba, Brazil, showed that walking for transportation was significantly associated with access to two or more rapid transit bus stations and commercial area proportion within a 500 m buffer, but not with bus stops, land use mix, and street connectivity ((Hino et al., 2014). A study conducted on adults from Bogota, Colombia, found significant associations between walking for transportation and access to *TransMilenio* bus stations (Lemoine et al., 2016). However, we did not found any literature in Latin American cities that analyzed different types of destinations such as those associated with food, health care, or physical activity and there was no literature exploring the influence of the mix of destinations, typically defined using a summed score of a variety different destinations (Gunn et al., 2017; King et al., 2015; McCormack et al., 2008) on walking trips in adults. Active transportation, hereby defined as walking and cycling can bring many co-benefits including a reduction in car and fossil fuel dependency, and improvements to social capital (Giles-Corti et al., 2010), especially in a megalopolis like Sao Paulo, where there are more than seven million cars on the streets (Department of Traffic from Sao Paulo State, 2018). Thus, it is important to examine who walks and how the built environment is associated with walking for transportation in adults in Sao Paulo city. Therefore, the aims of this study were: 1) To describe the profile of adults who walk for transportation in Sao Paulo city; and 2) To examine if some types of destinations and the mix of destinations are associated with walking for transportation amongst adults living in Sao Paulo city.

2. Material and methods

2.1. Sao Paulo city

Sao Paulo is the biggest municipality in Brazil, with 12,176,866 inhabitants. Its mean population density is about 7398.26 inhabitants per km^2 (Brazilian Institute of Statistics and Geography, 2018) spatially heterogeneous over the territory. Although as a whole its human development index is considered high (HDI = 0.805), it varies from 0.70 to 0.98 in a markedly socio-spatial pattern of inequality. São Paulo presents the highest gross domestic product of all 5570 cities in Brazil. After the Second World War, Sao Paulo underwent an extended period of unplanned urban sprawl. However, in 2014 a new Master Plan with the objective of decreasing environmental inequities for people living in this city was approved (Department of Urbanism of the Sao Paulo city, 2014).

2.2. Sao Paulo health survey

We conducted a cross-sectional analysis using the Sao Paulo Health Survey dataset of 2014–2015. This survey was conducted with a random sample of Sao Paulo city according to five health administration areas (South, East, Midwest, North, and Southeast), census tracts, and the households in the census tracts. Our final study comprised 150 census tracts (30 in each area), 2246 households, and 3145 people. More details about the sample selection are described elsewhere (Florindo et al., 2017).

2.3. Walking for transportation

Walking for transportation was measured using the International Physical Activity Questionnaire (IPAQ) long version. The module was standardized to capture the frequency (times per week) and duration (minutes per day) of walking for transportation. The questions were: "1) How many days in a typical week did you walk for at least 10 min continuously going from one place to another?"; 2) When you walk to go to from one place to another, how much time do you spend per day?". In this case, walking for transportation was a trip made exclusively on foot.

The survey modules of leisure and transportation from the questionnaire were validated in a sample of the Sao Paulo adult population using accelerometer data (Garcia et al., 2013).

2.4. Covariates

The covariates were: sex (male, female); age groups (18–29 years, 30–39 years, 40–49 years, 50–59 years, and 60 years or older); levels of education (incomplete elementary school, completed elementary to incomplete high school, completed high school, undergraduate incomplete or more); marital status (married/de facto, single, divorced/separated/widowed); obesity status based on body mass index (yes $\geq 30\,kg/m^2$, no $< 30\,kg/m^2$); smoking (yes or no); self-reported health (excellent/good/very good; or regular/bad/very bad); employment situation (work: yes or no); car or motorcycle ownership in family (yes or no); length of living in the same residence (up to 1 year, between 1 and 5 years, > 5 years); family per capita income (total residence income divided by total of people who lived in the same residence and analyzed in quartiles); health administration areas (East, South, Southeast, North, Midwest); and safety perception for physical activity (score that varied between 0 and 2 and that was composed by 2 questions about safety perception for physical activity during the day: yes or no; and during the night: yes or no).

2.5. Built environment variables

The built environment factors examined in this study were: 1) bus stops; 2) train and subway stations; 3) parks; 4) squares; 5) public recreation centres; 6) bike paths; 7) primary health care units; 8) supermarkets; 9) food stores; 10) bakeries; and 11) coffee-shops (Table 1). These types of destinations are part of the design and diversity of neighborhoods within their 5Ds framework (Ewing and Cervero, 2001).

Built environment factors 1 to 7 were obtained using December 2015 georeferenced open street data from Sao Paulo and we calculated the number of bus stops, train or subway stations, parks (according to Municipal and State Government), squares (according to Municipal and State Government), public recreation centres (places with facilities for sports and physical exercises), the length of bike paths in meters (that are used for cycling, walking and running in Sao Paulo city) and the number of primary health care units (that may have physical activity programs in Sao Paulo city) (Municipality Government of Sao Paulo, 2016). Built environment factors 8 to 11 were obtained until November of 2016 using the Health Surveillance Registration database from Sao Paulo city associated with National Economic Activity Classification and database presented facilities with commercial activities in November 2016 (20,131). After geocoding the facilities were grouped in categories according to food establishment types in Brazil. We calculated the number of: supermarkets (places of purchase foods and cleaning products); food stores (places for food consumption including restaurants and fast-foods); bakeries; and, coffee-shops.

We used Geographic Information System ArcMap software (version 10.3, Redlands, CA, USA) to delineate radial buffers of 500 m and 1,000 m based on the geographic coordinates of the adults' residential addresses. Destinations within 400 m and 1,500 m from residences represent distances that people can access by walking between five minutes and 15 min respectively (McCormack et al., 2008).

Table 1
Descriptive statistics of built environment variables according to the residential address, Sao Paulo Health Survey, 2014–2015.

Facilities	Buffers	Mean (SD)	Range	%[a]	Median (IQR)[b]	Variable[c]	Cut points		
Bus stop	500	10.3 (10.4)	0–43	57.7	9 (19; 0)	Binary	0	≥1	
Bus stop	1000	67.3 (25.9)	0–211	99.9	68 (82; 53)	Categoric	< 57	≥58-76	≥77
Train or subway stations	500	0.06 (0.3)	0–3	4.7	0 (0; 0)	Binary	0	≥1	
Train or subway stations	1000	0.2 (0.8)	0–7	10.2	0 (0; 0)	Binary	0	≥1	
Primary health care units	500	0.5 (0.6)	0–3	44.4	0 (1; 0)	Binary	0	≥1	
Primary health care units	1000	1.8 (1.1)	0–6	91.8	2 (2; 1)	Binary	≤1	≥2	
Bike paths (meters)	500	303.7 (638.0)	0–4022.7	29.3	0 (313.3; 0)	Binary	0	≥1	
Bike paths (meters)	1000	1214.2 (1999.2)	0–12567.3	52.4	204.7 (1843.4; 0)	Categoric	0	1–1500	> 1500
Parks	500	0.2 (0.4)	0–2	17.3	0 (0; 0)	Binary	0	≥1	
Parks	1000	0.8 (0.5)	0–3	73.6	1 (1; 0)	Binary	0	≥1	
Squares	500	2.1 (2.7)	0–15	66.4	1 (3; 0)	Binary	0	≥1	
Squares	1000	8.4 (8.8)	0–47	87.5	7 (11; 1)	Categoric	0	1–10	≥11
Recreation Centres	500	0.1 (0.3)	0–2	10.5	0 (0; 0)	Binary	0	≥1	
Recreation Centres	1000	0.4 (0.6)	0–3	33.4	0 (1; 0)	Binary	0	≥1	
Supermarkets	500	3.2 (4.0)	0–32	84.8	2 (4; 1)	Categoric	≤1	2–3	≥4
Supermarkets	1000	12.1 (13.2)	0–114	97.7	10 (14; 6)	Categoric	≤7	8–12	≥13
Bakeries	500	0.05 (0.2)	0–2	4.8	0 (0; 0)	Binary	0	≥1	
Bakeries	1000	0.2 (0.5)	0–4	17.9	0 (0; 0)	Binary	0	≥1	
Food stores	500	8.8 (26.2)	0–245	82.3	2 (5; 1)	Binary	0	≥1	
Food stores	1000	33.6 (86.7)	0–662	96.6	10 (26; 4)	Categoric	≤5	6–18	≥19
Coffee-shops	500	0.5 (2.2)	0–29	14.1	0 (0; 0)	Binary	0	≥1	
Coffee-shops	1000	2.1 (7.6)	0–60	35.3	0 (1; 0)	Categoric	0	1	≥2
Mix of destinations (score)	500	3.07 (1.70)	0–8	–	3 (4; 2)	Categoric	≤2	3	≥4
Mix of destinations (score)	1000	3.67 (2.21)	0–9	–	4 (5; 2)	Categoric	≤2	3–4	≥5

[a] Presence at least one facility (yes or no).
[b] IQR (interquartile range: percentile 75 and 25).
[c] Standardization for statistical models.

Within each buffer around the participants' residential addresses we recorded: (1) the presence or absence of built environment variables (yes or no); and (2) the number of built environment variables. For bike paths we calculated the length in meters inside the buffers. The objective was to evaluate the availability and accessibility of destinations and services related to food, health, and physical activity.

Table 2
Descriptive statistics and prevalence ratio of walking for transportation in adults according to social, demographics, health, and environment variables, Sao Paulo Health Survey, 2014–2015.

Variables	Total sample (n = 3145) %; mean (SE)[a]	Prevalence ratio (PR) to walking for transportation PR (CI95% (%)[b]
Sex		
Female	53.7	1
Male	46.3	1.00 (0.93–1.07)
Age group (years)		
18-29	24.7	1
30-39	22.8	0.98 (0.88–1.08)
40-49	18.4	1.02 (0.91–1.14)
50-59	15.7	1.03 (0.93–1.16)
60 years or older	18.4	**0.88 (0.77–1.00)[#]**
Mean (SE) - years	43.2 (42.3)	
Education		
Incomplete elementary school	17.6	1
Elementary to incomplete high school	24.1	1.13 (1.00–1.27)
Complete high school	28.7	**1.16 (1.03–1.30)[#]**
Undergraduate incomplete to complete	29.2	**1.16 (1.02–1.33)[#]**
Obesity		
Body mass index ≥ 30 kg/m^2	21.0	1
Body mass index < 30 kg/m^2	79.0	**1.10 (1.01–1.20)[#]**
Mean (SE) - Body mass index (kg/m^2)	26.3 (0.11)	
Smoking		
No	82.6	1
Yes	17.4	1.08 (0.98–1.19)
Self-report of health		
Regular/bad/very bad	27.7	1
Good/very good/excellent	72.3	1.02 (0.94–1.11)
Employees		
No	34.9	1
Yes	65.1	1.00 (0.93–1.08)
Car or motorcycle ownership		
No	42.8	1
Yes	57.2	**0.82 (0.76–0.88)[#]**
Safety perception for physical activity		
Is safe during the day and night?		
Not during the day and night	29.4	1
Yes, or during the day or during the night	51.6	1.01 (0.92–1.10)
Yes, during the day and during the night	19.0	0.91 (0.80–1.02)
Mean (SD) – score (0–2 points)	0.90 (0.03)	
Family per capita *income (quartiles)*		
Lowest	23.1	1
Second	23.8	1.03 (0.93–1.16)
Third	25.0	1.00 (0.90–1.12)
Highest	28.1	1.10 (0.98–1.23)
Mean (SE) – Brazilian Currency	1332.0 (70.8)	
Health administration area where people living		
North	19.8	1
Midwest	14.5	0.99 (0.81–1.20)
Southeast	25.7	1.03 (0.90–1.12)
South	20.5	0.86 (0.71–1.04)
East	19.5	1.05 (0.91–1.20)
Length in the same residence		
≤1 year	12.4	1
> 1 year < 5 years	21.0	0.99 (0.88–1.11)
> 5 years	66.6	1.00 (0.89–1.11)
Mean (SE) – months	185.1 (5.75)	
Walking for transportation		
% yes	58.0	
% ≥ 150 min per week	19.0	
Mean (SE) – minutes per week	96.6 (5.1)	

#$p < 0.05$.
[a] Weighted percentage.
[b] Adjusted by all variables in Table 1.

The mix of destinations was characterized by the presence and accessibility from residences of services including food stores (restaurants and fast-foods), coffee-shops, bakeries, supermarkets, open spaces (squares, parks and bike paths), health services, recreation centres, bus stops and transportation stations (train or subway) which have been shown to be associated with walking trips in the Australian context (Gunn et al., 2017; King et al., 2015; McCormack et al., 2008).

Table 3
Association between walking for transportation (yes or no) and built environment factors according to buffer size.

Exposure variables	Buffer size (meters)	Categorization of variables	Walking for transportation (any walking x no walking)	Walking for transportation (any walking x no walking)
			Model 1[a] OR (95%CI)	Model 2[b] OR (95%CI)
Parks	500	0	1	1
		≥1	1.06 (0.73–1.53)	1.11 (0.75–1.64)
Parks	1000	0	1	1
		≥1	0.96 (0.69–1.33)	1.03 (0.72–1.47)
Squares	500	0	1	1
		≥1	1.02 (0.75–1.39)	1.04 (0.75–1.43)
Squares	1000	0	1	1
		1–10	0.91(0.63–1.32)	1.04 (0.71–1.54)
		≥11	1.13 (0.78–1.64)	1.10 (0.72–1.67)
Bike paths (meters)	500	0	1	1
		≥1	1.29 (0.94–1.78)	1.17 (0.84–1.62)
Bike paths (meters)	1000	0	1	1
		1-1500	1.26 (0.87–1.83)	1.12 (0.76–1.64)
		> 1500	1.36 (0.93–1.97)	1.26 (0.87–1.83)
Recreation centres	500	0	1	1
		≥1	0.87 (0.59–1.27)	0.83 (0.55–1.24)
Recreation centres	1000	0	1	1
		≥1	0.95 (0.69–1.30)	0.82 (0.60–1.12)
Train or subway stations	500	0	1	1
		≥1	**1.87 (1.01–3.46)**#	1.34 (0.70–2.58)
Train or subway stations	1000	0	1	1
		≥1	**2.00 (1.22–3.29)**#	**2.07 (1.23–3.50)** #
Bus stop	500	0	1	1
		≥1	0.89 (0.62–1.27)	0.99 (0.69–1.43)
Bus stop	1000	< 57	1	1
		≥58-76	1.27 (0.92–1.76)	1.21 (0.85–1.71)
		≥77	1.33 (0.92–1.91)	1.22 (0.84–1.78)
Primary health care units	500	0	1	1
		≥1	0.98 (0.76–1.27)	0.96 (0.73–1.27)
Primary health care units	1000	≤1	1	1
		≥2	1.31 (0.99–1.72)	**1.41 (1.03–1.92)** #
Supermarkets	500	≤1	1	1
		2–3	1.24 (0.92–1.66)	1.15 (0.84–1.59)
		≥4	**1.52 (1.07–2.16)** #	1.42 (0.97–2.08)
Supermarkets	1000	≤7	1	1
		8–12	1.17 (0.85–1.63)	1.22 (0.87–1.71)
		≥13	1.36 (0.95–1.95)	**1.52 (1.03–2.24)**#
Bakeries	500	0	1	1
		≥1	**2.01 (1.02–3.96)** #	**3.23 (1.47–7.10)** #
Bakeries	1000	0	1	1
		≥1	**1.83 (1.21–2.78)** #	**2.14 (1.37–3.33)** #
Food stores	500	0	1	1
		≥1	1.02 (0.72–1.45)	0.96 (0.66–1.41)
Food stores	1000	≤5	1	1
		6–18	1.01 (0.71–1.43)	1.19 (0.82–1.72)
		≥19	1.17 (0.80–1.72)	1.32 (0.83–2.06)
Coffee-shops	500	0	1	1
		≥1	**1.51 (1.02–2.23)** #	1.49 (0.94–2.36)
Coffee-shops	1000	0	1	1
		1	1.05 (0.69–1.58)	1.06 (0.70–1.62)
		≥2	1.20 (0.82–1.76)	1.28 (0.83–1.97)

# $p < 0.05$.
[a] Model without adjusted.
[b] Model adjusted by sex, age, education level, car or motorcycle ownership, time living in the same residence, place where people living, score of safety perception for physical activity, presence of obesity, and family per capita income.

2.6. Statistical analysis

We calculated the prevalence ratio of walking for transportation according to social, demographics, health, work, and environment characteristics. We used Poisson regression and complex sample design according to the census tract (primary unit of sample) in five health areas in Sao Paulo (strata), and the sample weight. This weight took into account the design effect, post-stratification by sex and age, and the non-response rate.

We used two outcomes: 1) Some walking for transportation: yes or no; 2) Regular walking for transportation: < 150 min per week

Table 4
Association between walking for transportation (< 150 min/week x ≥ 150 min/week) and built environment factors according to buffer size.

Exposure variables	Buffer size (meters)	Categorization of variables	Walking for transportation (< 150 min/week x ≥ 150 min/week)	Walking for transportation (< 150 min/week x ≥ 150 min/week)
			Model 1[a] OR (95%CI)	Model 2[b] OR (95%CI)
Parks	500	0	1	1
		≥1	0.90 (0.61–1.33)	0.82 (0.55–1.23)
Parks	1000	0	1	1
		≥1	0.85 (0.61–1.18)	0.74 (0.53–1.03)
Squares	500	0	1	1
		≥1	1.01 (0.74–1.39)	0.95 (0.69–1.30)
Squares	1000	0	1	1
		1–10	0.91 (0.63–1.31)	0.94 (0.64–1.38)
		≥11	0.98 (0.69–1.40)	0.85 (0.57–1.28)
Bike paths (meters)	500	0	1	1
		≥1	1.10 (0.79–1.52)	1.03 (0.75–1.43)
Bike paths (meters)	1000	0	1	1
		1-1500	1.17 (0.81–1.70)	1.02 (0.70–1.49)
		> 1500	1.09 (0.75–1.57)	1.08 (0.75–1.55)
Recreation centres	500	0	1	1
		≥1	0.87 (0.56–1.36)	0.72 (0.46–1.13)
Recreation centres	1000	0	1	1
		≥1	0.88 (0.64–1.21)	0.88 (0.65–1.21)
Train or subway stations	500	0	1	1
		≥1	**2.31 (1.26–4.23)**[#]	1.86 (0.98–3.53)
Train or subway stations	1000	0	1	1
		≥1	1.47 (0.93–2.33)	**1.66 (1.02–2.69)**[#]
Bus stop	500	0	1	1
		≥1	1.11 (0.80–1.53)	1.31 (0.93–1.84)
Bus stop	1000	< 57	1	1
		≥58-76	0.75 (0.53–1.06)	0.77 (0.54–1.10)
		≥77	1.12 (0.79–1.60)	0.93 (0.65–1.34)
Primary health care units	500	0	1	1
		≥1	0.91 (0.69–1.20)	0.81 (0.61–1.09)
Primary health care units	1000	≤1	1	1
		≥2	1.02 (0.76–1.37)	0.96 (0.70–1.32)
Supermarkets	500	≤1	1	1
		2–3	1.20 (0.86–1.67)	0.99 (0.70–1.39)
		≥4	1.23 (0.85–1.79)	0.93 (0.63–1.38)
Supermarkets	1000	≤7	1	1
		8–12	1.12 (0.79–1.58)	1.03 (0.73–1.45)
		≥13	1.19 (0.83–1.71)	1.03 (0.69–1.52)
Bakeries	500	0	1	1
		≥1	1.78 (0.96–3.33)	1.88 (0.95–3.71)
Bakeries	1000	0	1	1
		≥1	1.39 (0.94–2.05)	1.49 (0.99–2.23)
Food stores	500	0	1	1
		≥1	1.03 (0.71–1.49)	0.95 (0.64–1.39)
Food stores	1000	≤5	1	1
		6–18	0.89 (0.62–1.29)	1.11 (0.76–1.61)
		≥19	1.12 (0.77–1.62)	1.24 (0.80–1.93)
Coffee-shops	500	0	1	1
		≥1	1.25 (0.84–1.85)	1.13 (0.71–1.79)
Coffee-shops	1000	0	1	1
		1	0.84 (0.55–1.28)	0.82 (0.54–1.26)
		≥2	1.13 (0.78–1.65)	1.04 (0.68–1.59)

[#] $p < 0.05$.
[a] Model without adjusted.
[b] Model adjusted by sex, age, education level, car or motorcycle ownership, time living in the same residence, place where people living, score of safety perception for physical activity, presence of obesity, and family per capita income.

or ≥150 min per week. All built environment variables were analyzed as independent variables in each buffer size (500 m and 1000 m) according to the number of items within the buffers that were classified in two or three levels categories according to distribution of each variable to create similar groups for the analyses for dichotomous variables (above and below) and tertiles for categorical variables (Table 1).

We calculated a destination mix score for each buffer size according to Australian studies (King et al., 2015; Gunn et al., 2017) since studies show that destination diversity is also associated with walking for transportation (McCormack et al., 2008). Firstly, we calculated the median for each built environment variable. Secondly, people who were above the median were scored 1 and the people that were equal to below were scored 0. Finally, we divided the final score into three categories according to distribution to create similar groups for analysis (Table 1).

The modeling took into account clustering by census tract and households in two stages: 1) Firstly, we conducted the analysis of walking for transportation with each built environment variable in each buffer size without adjustment; 2) Secondly, we repeated the analysis adjusting for sex, age, education, obesity, car or motorcycle ownership, time living in the same residence, health administration area, safety perception score for physical activity, and family per capita income; 3) Thirdly, we calculated all analysis adjusted for mix of destinations. Missing observations varied between n = 3 for smoking to n = 648 for family per capita income. The results are presented as odds ratios (OR) and 95% confidence intervals. All analyses were conducted in Stata software using the xtmelogit command (Stata version SE 12.1, StataCorp).

2.7. Ethical committee

The Ethics Committee of the School of Arts, Sciences, and Humanities at the University of Sao Paulo approved this study (process number 55846116.6.0000.5390).

3. Results

People with high education, and who were not obese, had a higher prevalence of walking for transportation. People with families with cars or motorcycles ownership and with 60 years old or more were significantly less likely to walk for transportation (Table 2).

While most of the sample undertook some walking for transportation, only one-fifth walked 150 min or more per week (Table 2).

The presence of train or subway stations, two or more primary health care units, 13 or more supermarkets, and the presence of bakeries were associated with some walking for transportation within 1,000 m (Table 3). In addition, people who had a presence of bakeries within 500 m had a greater likelihood for walking for transportation (Table 3).

People who lived within 1,000 m of train or subway stations had 65% more likely to walk for transportation for 150 min or more per week (OR: 1.65, 95% CI: 1.02–2.68) than people without these facilities (Table 4). This was the only built environment variable significantly associated with regular walking for transportation.

The mix of destinations was significantly associated with walking for transportation within 500 m after adjustment for sex, age, education level, obesity status, safety perception score for physical activity, car or motorcycle ownership, time living in the same residence, health administration area where people living, and family per capita income (Table 5). People with access to the highest tertiles of destinations had a 40% greater chance of undertaking some walking for transportation (OR = 1.40 IC95% 1.01–1.93). . However, we did not find the same results in the analyses of the regular walking for transportation (150 min or more per week) (Table 5).

4. Discussion

The main result of this study showed that people living within 500 m of a greater mix of destinations had a greater likelihood of undertaking some walking for transportation. The presence of train or subway stations within 1,000 m was significantly associated

Table 5
Walking for transportation and mix of destinations according to buffer size.

Exposure variables	Buffer size (meters)	Categorization of variables	Walking for transportation (no x any)	Walking for transportation (< 150 min/ ≥ 150 min)
			Model[a] OR (95%CI)	Model[a] OR (95%CI)
Mix of destinations	500	Lowest	1	1
		Middle	1.23 (0.89–1.70)	0.96 (0.67–1.38)
		Highest	**1.40 (1.01–1.93)**[#]	1.21 (0.86–1.69)
Mix of destinations	1000	Lowest	1	1
		Middle	1.11 (0.78–1.58)	0.94 (0.66–1.36)
		Highest	1.30 (0.88–1.93)	0.90 (0.61–1.34)

[#] $p < 0.05$.
[a] Model adjusted by sex, age, education level, car or motorcycle ownership, time living in the same residence, place where people living, score of safety perception for physical activity, presence of obesity, and family per capita income.

with walking for transportation for 150 min or more per week. In addition, the presence and density of different types of destinations such as primary health care units and supermarkets in 1,000 m, and bakeries in 500 m and 1,000 m were significantly associated with some walking for transportation.

The profile of walkers identified in this study was different from other research in Brazil. One previous study with a representative sample of adults from three cities in Brazil (Recife, Northeast; Curitiba, South; and Vitoria, Southeast) showed that education was inversely associated with walking for transportation (Reis et al., 2013). Similar results were found in a cohort study with Australian adults from Brisbane, where the odds of walking for transportation were higher in the least educated group (Rachele et al., 2015). However, a cohort study of adults from Paris, France, showed that high education level was associated with more likelihood for walking for transportation than low education levels (Karusisi et al., 2014).

People not obese were more likely to walk for transportation. However, people with families with cars or motorcycles ownership and people aged 60 years or more were less likely to walk for transportation. The survey conducted with adults in three Brazilian cities did not find the same results (Reis et al., 2013). Another study with adults in low socioeconomic areas from the East zone in Sao Paulo city showed that good safety perception for physical activity was strongly associated with walking for transportation (Florindo et al., 2011).

In addition, study with adults from Curitiba also showed that the number of motor vehicles in households was inversely associated with walking for transportation (Lopes et al., 2018). Similarly, a study conducted in a low socioeconomic area in the East zone in Sao Paulo city showed that car ownership in households was significantly associated with transportation physical inactivity (Sa et al., 2013).

An important result of this study was to show that regular walking for transportation (150 min or more per week) was significantly associated with the presence of train or subway stations within 1,000 m. Other studies have also shown that the use of public transportation and the presence of large transportation systems are associated with walking trips. The cross-sectional study conducted with a representative sample from Curitiba, Brazil, showed that the number of days of public transportation use was significantly associated with walking for transportation (Lopes et al., 2018). In the same city, Hino et al. showed that people with access to two or more rapid bus or train stations within 500 m had a greater likelihood for walking for transportation than people without access (Hino et al., 2014). In Bogota, Colombia, a survey that was conducted with a representative sample of adults showed that people living within 500 m of *TransMilenio* stations had a greater likelihood of using the bus rapid system. In addition, this study showed that the *TransMilenio* users had a greater likelihood for walking for transportation that non-user(Lemoine et al., 2016). These results are similar in high income countries. A study conducted in the United States of America also found that the regular use of public transportation was significantly associated with walking for transportation (Zwald et al., 2014). Another study with adults from Perth, Australia, showed the presence of train or subway stations within 1,600 m buffers were significantly associated with walking for transportation in adults (Knuiman et al., 2014). In addition, the analysis of Danish National Health Survey showed that distances greater than 1 km from residences of public transportation stops such as train and subway stations, decreased the likelihood for active commuting (Djurhuus et al., 2014).

Sao Paulo has a large public transportation system. 37% of the population in Sao Paulo (~4.5 million) use public transport daily (Companhia do Metropolitano de Sao Paulo, 2018.). Trains and subways are integrated and there are 184 stations and 357 km of rail line in metropolitan area (Companhia do Metropolitano de Sao Paulo, 2019). Trips by bus and train increased more than 50% between 2007 and 2017 in metropolitan area of Sao Paulo (Companhia do Metropolitano de Sao Paulo, 2019). Our study demonstrated that the presence of these facilities within 1,000 m of residences is important markers for walking trips in Sao Paulo city. And this result is important because, in addition to health benefits, the growth of active transportation can contribute directly to a decrease in air pollution and an increase in social capital (de Nazelle et al., 2011; Woodcock et al., 2007).

Facilities like supermarkets, primary health care units within 1,000 m, and bakeries in 500 m and 1,000 m of residences were associated with some walking for transportation in our study of Sao Paulo adults. We have not found other publications that examined the influences of these specific facilities in walking for transportation in Latin American cities. However, a study conducted with 2349 adults from Melbourne, Australia, found that coffee-shops, small food stores and supermarkets located between 401 m and 800 m of residences were significantly associated with walking trips (Gunn et al., 2017). Our results build on this by showing that places with higher number of bakeries, supermarkets and primary health care units within 1,000 m of residences are associated with some walking for transportation in Sao Paulo city.

The main finding of this study was that the mix of destinations within 500 m was significantly associated with some walking for transportation. A number of studies using Australian data have found similar results with adults from Melbourne, Australia, where the destination mix was associated with walking trips (Gunn et al., 2017; King et al., 2015). Similarly, a systematic review of longitudinal studies from high-income countries showed that the accessibility of destinations and the land use mix were associated with the active transportation (Smith et al., 2017). However, we did not find significant associations with walking for transportation for 150 min or more per week. We believe that the mix of destinations can contribute to any walking trips, but higher levels of walking for transportation can depend on other built environment factors such as walkability, land use mix, street connectivity, pedestrian infrastructure, employment density, and aesthetics (Bentley et al., 2018; Ewing and Cervero, 2001; Kamruzzaman M et al., 2014; Knuiman et al., 2014; Rachele et al., 2018; Saelens and Handy, 2008; Zwald et al., 2014) which we did not evaluate in this study. Nevertheless, we believe that this result is very important because it can be used to plan neighborhoods that encourage people to some walk, particularly in cities like Sao Paulo where there are many environmental inequities (Department of Urbanism of the Sao Paulo city, 2014).

We did not find any significant association between walking for transportation and recreation centres, parks, squares or bike paths. Despite this, these variables could be important because open spaces like parks, squares, and bike paths are associated with leisure time walking in adults from Sao Paulo (Florindo et al., 2017). We did not find other research in Latin American cities that has examined these relationships. However, a study conducted in Bogota, Colombia, showed that public park density was associated with general walking in elderly people (Gomez et al., 2010). Similarly, another study showed that sports facilities were associated with general walking in adults from Melbourne, Australia (King et al., 2015). But, in both these studies walking for transportation was not analyzed separately.

This study has some limitations. We worked with radial buffers that may introduce measurement error (Oliver et al., 2007). Future analysis with network buffers around residences should be compared with radial buffers. We did not control for self-selection in the neighborhood (Giles-Corti et al., 2013). People who are active may choose to live in neighborhoods with better facilities for walking for transportation. Another limitation was the cross-sectional analyses. The interviews were conducted from August 2014 to December 2015, while some built environment variables were obtained towards the end of 2016. Only longitudinal studies could better clarify these relations. We did not evaluate other variables that are important for walking for transportation such as land use mix, population and employment density, aesthetics, pedestrian infrastructure, and street connectivity (Bentley et al., 2018; Ewing and Cervero, 2001; Knuiman et al., 2014; Rachele et al., 2018; Saelens and Handy, 2008; Kamruzzama et al., 2014;; Zwald et al., 2014). We did not evaluate land gradients and slope. This built environment variable can influence the walking in Sao Paulo. Finally, we evaluated only the built environment of residences and no other environments where physical activity may occur. At least one study has shown that the work environment is also important to walking for transportation in adults (Karusisi et al., 2014).

5. Conclusion

We found that people with high education and who were not obese, had a higher prevalence ratio for walking for transportation. The cars or motorcycles ownership in the families and aged 60 years or more were significantly less likely to walk for transportation. People with access to the highest tertile of the mix of destinations in 500 m had a greater likelihood of walking for transportation. The presence of train or subway stations within 1,000 m increased the likelihood of walk for transportation for 150 min or more per week. The presence of different types of destinations such as primary health care units, train or subway stations, the high density of supermarkets within 1,000 m and the presence of bakeries in 500 m and 1,000 m were significantly associated with some walking for transportation. Despite some limitations, our study has identified key aspects of the built environment that promote walking trips in adults from Sao Paulo. These results could be used to foster discussions about the planning of healthy neighborhoods in Sao Paulo city.

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