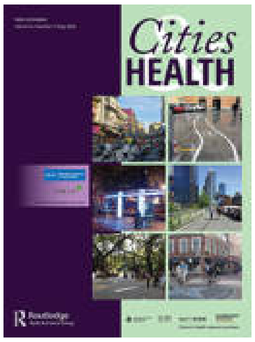

Cities & Health

ISSN: (Print) (Online) Journal homepage: https://www.tandfonline.com/loi/rcah20

Built environments for physical activity: a longitudinal descriptive analysis of Sao Paulo city, Brazil

Inaian Pignatti Teixeira, João Paulo dos Anjos Souza Barbosa, Ligia Vizeu Barrozo, Adriano Akira Ferreira Hino, Priscila Missaki Nakamura, Douglas Roque Andrade, Suzanne Mavoa, Gavin Turrell, Rodrigo Siqueira Reis & Alex Antonio Florindo

CITIES & HEALTH
https://doi.org/10.1080/23748834.2022.2127173

Routledge
Taylor & Francis Group

ORIGINAL SCHOLARSHIP

Check for updates

Built environments for physical activity: a longitudinal descriptive analysis of Sao Paulo city, Brazil

Inaian Pignatti Teixeira[a,b,c], João Paulo dos Anjos Souza Barbosa[c], Ligia Vizeu Barrozo[d], Adriano Akira Ferreira Hino[e], Priscila Missaki Nakamura[f], Douglas Roque Andrade[c,g,h], Suzanne Mavoa[i,j], Gavin Turrell[k,l], Rodrigo Siqueira Reis[m] and Alex Antonio Florindo[c,g,n]

[a]Minas Gerais State University, Passos, Brazil; [b]Study, Research and Scientific Support Group, Minas Gerais State University, Passos, Brazil; [c]Physical Activity Epidemiology Group, University of Sao Paulo, São Paulo, Brazil; [d]Department of Geography, School of Philosophy, Literature and Human Sciences, University of Sao Paulo, Sao Paulo, Brazil; [e]Health Sciences Graduate Program, School of Medicine and Life Sciences, Pontifical Catholic University of Paraná, Curitiba, Brazil; [f]Federal Institute of Education, Science and Technology of South of Minas Gerais- Campus Muzambinho, Muzambinho, Brazil; [g]School of Arts, Sciences and Humanities, University of Sao Paulo, Sao Paulo, Brazil; [h]Graduate Program in Social Change and Political Participation, School of Arts, Sciences and Humanities, University of Sao Paulo, Sao Paulo, Brazil; [i]Melbourne School of Population & Global Health, University of Melbourne, Melbourne, Australia; [j]Victoria Environmental Protection Authority (EPA), Victoria, Australia; [k]Centre for Urban Research, RMIT University, Melbourne, Australia; [l]Health Research Institute, University of Canberra, Canberra, Australia; [m]People health and Place Unit, Prevention Research Center, Brown School, Washington University in Saint Louis, St Louis, MO, USA; [n]Graduate Program in Nutrition in Public Health, School of Public Health, University of Sao Paulo, Sao Paulo, Brazil

RESUMEN
Las políticas y los planes de la ciudad juegan un papel importante en la promoción de la actividad física a través de cambios en el diseño urbano y los sistemas de transporte. Los objetivos de este estudio fue describir los cambios longitudinales y relevantes en el entorno construido para la actividad física en el tiempo libre y los viajes activos en la ciudad de Sao Paulo, Brasil, entre 2015 y 2020; describir estos cambios según las regiones de la ciudad, los ingresos de las secciones censales y las zonas de amortiguamiento alrededor de las residencias de los participantes en una cohorte. Para ello se utilizarán datos de bibliotecas públicas en línea, cotejados con las secretarías municipales y estatales específicas, se midieron plazas públicas, parques, instalaciones deportivas, clubes comunitarios, gimnasios al aire libre, ciclovías, estaciones de tren o metro, terminales de autobuses y unidades de salud. Para cuantificar estos atributos alrededor de las residencias, se adoptaron cuatro zonas de amortiguamiento diferentes: zonas de amortiguamiento radiales de 500 m y 1000 m y zonas de amortiguamiento de red de 500 m y 1000 m. Se observó un aumento en gimnasios al aire libre (+109,6%), ciclovías (+67,7%), estaciones de tren o metro, terminales de ómnibus (+15,4%), instalaciones deportivas (+12,0%) y plazas públicas (+8,7%). Sin embargo, los cambios difirieron según la región, los ingresos del distrito censal y el área residencial. Los resultados pueden servir para fomentar una discusión sobre los efectos de las políticas locales que se están ejecutando. Además, este estudio destaca desigualdades importantes en las ciudades a través de los diferentes niveles evaluados.

RESUMO
As políticas e planos da cidade desempenham um papel importante na promoção da atividade física por meio de mudanças no desenho urbano e nos sistemas de transporte. Os objetivos deste estudo foram descrever as mudanças longitudinais no ambiente construído, relevantes para a atividade física de lazer e viagens ativas na cidade de São Paulo, Brasil, entre 2015 e 2020; descrever essas mudanças segundo as regiões da cidade, renda dos setores censitários e áreas no entorno das residências dos participantes de um estudo de coorte. Utilizando dados de bibliotecas públicas online, confirmados pelas secretarias municipais e estaduais, foram mensurados: praças públicas, parques, instalações esportivas, clubes comunitários, academias ao ar livre, ciclovias e ciclofaixas, estações de trem e metrô, terminais de ônibus e unidades de saúde. Para quantificar esses atributos no entorno das residências, foram adotados quatro buffers diferentes: *buffers* radiais de 500 m e 100 m e *buffers network* de 500 m e 1000 m. Foi observado um aumento em academias ao ar livre (+109,6%), ciclovias (+67,7%), estações de trem ou metrô, terminais de ônibus (+15,4%), instalações esportivas (+12,0%) e praças públicas (+8,7%). No entanto, as mudanças diferiram de acordo com a região, renda do setor censitário e área de residência. Os resultados desse estudo podem servir para fomentar uma discussão sobre os efeitos das políticas locais que estão sendo executadas. Além disso, este estudo destaca importantes disparidades nas cidades entre os diferentes níveis avaliados.

ARTICLE HISTORY
Received 24 May 2022
Accepted 17 September 2022

PALABRAS CLAVE
Entorno Construido; Desigualdad; Actividades Físicas Recreativas; Transporte activo; Evaluación, Cohorte

PALAVRAS-CHAVE
Ambiente Construído; Iniquidade; Atividade física no tempo livre; Deslocamento ativo; Monitoramento; Coorte

KEYWORDS
Built environment; inequality; leisure-time physical activity; active transportation; monitoring; cohort

CONTACT Inaian Pignatti Teixeira inaian.teixeira@uemg.br Minas Gerais State University, Passos, Brazil
Supplemental data for this article can be accessed online at https://doi.org/10.1080/23748834.2022.2127173

ABSTRACT
City policies and plans play an important role in promoting physical activity through changes in the urban design and transportation systems. The objectives of this study were to describe longitudinal changes in the built environment relevant to leisure-time physical activity and active travel in Sao Paulo city, Brazil, between 2015 and 2020; to describe these changes according to regions of the city, census tracts' income, and buffer zones around the residences of participants in a cohort. Using data from public online libraries, cross-checked with the specific municipal and state secretariats, the following were measured: public squares, parks, sports facilities, community clubs, outdoor gyms, bike paths, train or subway stations, bus terminals, and primary health care units. To quantify these attributes around the residences, four different buffers: 500 m and 100 m radial buffers and 500 m and 1000 m network buffers were adopted. An increase was observed in outdoor gyms (+109.6%), bike paths (+67.7%), train or subway stations, bus terminals (+15.4%), sports facilities (+12.0%), and public squares (+8.7%). However, the changes differed according to the region, census tract income, and residential area. The results can serve to foster a discussion on the effects of local policies being executed. In addition, this study highlights important disparities in cities through the different levels evaluated.

Background

According to the World Health Organization (WHO), nearly eight out of ten global deaths related to non-communicable diseases are from low- and middle-income countries (World Health Organization 2021). In Brazil, 75% of all deaths are attributed to non-communicable diseases (Malta *et al.* 2017) with a continued increase in the same among adults aged 30-69 years old (Malta *et al.* 2020) since 2015.

Physical inactivity is the fourth leading risk factor for non-communicable diseases (World Health Organization 2022). In Brazil, 32,410 deaths (of all types) were attributed to physical inactivity in 2017 (Silva *et al.* 2020). To mitigate and reverse such trends, the WHO has recently published a Global Action Plan on Physical Activity 2018–2030 (World Health Organization 2018). A core objective of this plan is to create active environments as an effective strategy for promoting physical activity. Active environments include well-planned cities that encourage walking, cycling, and public transport use, which may help reduce the incidence of non-communicable diseases while also promoting population health and wellbeing (Jáuregui *et al.* 2021). The frequency of adults physically active in the leisure time (at least 150 min of moderate physical activity per week) grew from 30.3% in 2009 to 36.8% in 2020 (average increase of 0.71 pp/year) while in the commuting context remained stable (17.0% in 2009 and 13.3% in 2020) (Brazil 2021).

In Brazil, a legal framework (The City Statute) aimed at strengthening local planning and land management toward more equitable and sustainable urban development was approved by the Brazilian Congress in 2001 (Câmara 2010). Sao Paulo, the city with the largest population in South America, implemented a New Master Plan in 2014 that is scheduled to be reviewed in 2022. This plan defines a set of guidelines for the city's development and growth by 2030 (São Paulo 2014). The main goals of the Sao Paulo Master Plan include (a) addressing social and economic inequalities by improving access to housing and jobs through land-use and zoning changes; (b) improving access to and quality of public transit and active transportation; and (c) increasing the number of parks in the city. These goals are also supported by other local policies, including the Urban Mobility Plan (Prefeitura do Município de São Paulo 2015), and Pedestrian Statute (Prefeitura do Município de São Paulo 2020).

Given that macro-level environmental and policy interventions (such as the Master Plan and the Urban Mobility Policy) play an important role in promoting physical activity in urban settings (Owen *et al.* 2004, Smith *et al.* 2017, Panter and Jone 2010, Kärmeniemi *et al.* 2018, Cauwenberg *et al.* 2011, Wendel-Vos *et al.* 2007, Duncan *et al.* 2005, Humpel *et al.* 2002, Bauman *et al.* 2012, Cunningham and Michael 2004, Barnett *et al.* 2017, Saelens and Handy 2008), their effects on the health of the population should be routinely evaluated, monitored (Brownson *et al.* 1997), and described. Regular evaluations of the environmental interventions through policies may encourage public health agencies and policymakers to maintain or adjust these actions (Oldenburg *et al.* 2008).

Additionally, to formulate city-wide, macro-level environmental and policy interventions while taking into account (1) the growing effort to reduce environmental inequities in terms of access and choice for physical activity (World Health Organization 2018, Edwards and Tsouros 2012, Jacobs *et al.* 2019); and (2) the individual and combined effects of socio-economic contexts and built environments on health status (Schüle and Bolte 2015, Sharp and Kimbro 2021, Galán *et al.* 2021), it is also important to consider how these changes happen across different divisions of a given city such as regions (i.e. downtown vs. peripheral areas), income groups, neighborhoods, and homes.

Therefore, the aims of this study were (1) to describe longitudinal changes in the built environment relevant leisure-time physical activity and active

Table 1. Brief description of the eight built environment attributes adopted for the present study.

Built environment attributes	Brief description	Unit
Public squares	Open squares, public and urban spaces aimed at leisure and the coexistence of the population like pocket parks and usually, contain vegetation and can also have built elements	Square kilometers
Parks	Building-free green space, typically characterized as public space, in which there is typically an abundance of vegetation and unpaved areas, but located within an urban region	Square kilometers
Sports facilities	Public schools and public sports centers can be included gyms, sports fields, swimming pools and classes with physical education professionals	Map point
Community clubs	Small public facilities organized by community associations	Map point
Outdoor gyms	Gymnastic equipment that are installed in squares or in other public space for free community use	Map point
Bike paths	Cycling infrastructure that includes cycle path (with a physical segregation) and cycle lane (without a physical segregation)	Linear meters
Train or subway stations, and bus terminals	Large stations for public transportation	Map point
Primary health care units	Units focused on primary health care in public health system	Map point

travel in Sao Paulo city, Brazil, between 2015 and 2020; (2) to describe the longitudinal changes seen across different regions of the city, income groups, and population densities; and (3) to describe these observed longitudinal changes in the form of a cohort study.

Material and methods

Setting

This paper is part of the Health Survey of Sao Paulo: Physical Activity and Environment ('ISA – Physical Activity and Environment') (Florindo *et al.* 2021), which is a prospective multilevel analysis of a cohort of individuals living in Sao Paulo City, Brazil. The target area of this study is Sao Paulo city, which has an estimated population of 12,396,372 inhabitants living in a territorial area of 1,521.1 km^2 (Instituto Brasileiro de Geografia e Estatistica – IBGE 2020) resulting in a demographic density of 8,149.6 inhabitants/km^2 (Malta *et al.* 2017, Instituto Brasileiro de Geografia e Estatistica – IBGE 2020). In the most recently conducted national census (in 2010), the data collected on Sao Paulo showed: 92.6% of households with adequate sanitation facilities, 74.8% of urban households on public streets with trees, and 50.3% of urban households on public streets with adequate urbanization (presence of manholes, sidewalks, pavements, and curbs). In 2018, the per capita income in Sao Paulo city was R$ 1,452 Brazilian reais ($276.14 US dollars) (São Paulo Secretaria Municipal da Saúde 2015) and the city showed deep socioeconomic inequalities (Marques and Saraiva 2017).

Built environment data collection

There is cross-sectional evidence that public squares, parks, bike paths, train and subway stations, primary health care units, and a mix of destinations are associated with leisure-time walking, cycling and walking for transportation, and sedentary behavior in adults living in Sao Paulo city, Brazil (Florindo *et al.* 2017, 2018, 2019, Nogueira *et al.* 2018). Therefore, quantitative data was gathered on the following built environment attributes: (1) public squares, (2) parks, (3) sports facilities, (4) community clubs, (5) outdoor gyms, (6) bike paths, (7) train and subway stations and bus terminals, and (8) primary health care units. A brief description of each built environment attribute, along with the unit used to quantify it, is presented in Table 1.

The data on built environment attributes were gathered from several sources. The data were obtained, in 2015 and November 2020, from the Sao Paulo Municipal Government's public online library of geospatial databases (GEOSAMPA - http://geosampa.prefeitura.sp.gov.br/PaginasPublicas/_SBC.aspx), and cross-with databases of the specific municipal/state secretariats and laws/decrees. All attributes were investigated for the years 2015 and 2020, using the same methodology for both years.

Descriptive analyses

We undertook descriptive analyses of built environment attributes at four levels: (1) city, (2) health administrative area (South, East, North, Southeast, Downtown, and West) – not adjusted and adjusted per inhabitants (see population in Table 2) quartiles of census tracts' income, and (4) buffers around the residences of the cohort members of the 'ISA – Physical Activity and Environment' (Florindo *et al.* 2021).

The descriptive parameters were calculated for all built environment attributes by year. The absolute, relative, and percentile differences between the parameters determined for 2015 and 2020 were also calculated for each scenario.

Data on population and census tract income were obtained from the Brazilian Institute of Geography and Statistics (IBGE, in Portuguese) which was based on the 2010 census. For the fourth level, buffers around the residences of the cohort members of the ISA – Physical Activity and Environment, only those who were successfully interviewed during both time periods (2014/2015 and 2020/2021) were included.

Table 2. Estimated population, in millions, used for adjusted analyses considering the health administrative areas in Sao Paulo city, Brazil.

	2015	2020
Downtown	0.45	0.46
West	1.06	1.08
East	2.44	2.51
North	2.27	2.31
Southeast	2.69	2.71
South	2.68	2.80
Sao Paulo city	11.58	11.87

Source: Brazilian Institute of Geography and Statistics (IBGE)[33].

Table 3. Sample loss of the longitudinal ISA – physical activity and environment study.

	n	%
Participants not located	1567	38.8
More than six scheduled interviews without success	382	9.5
Refusals	201	5.0
Relocation from Sao Paulo	149	3.7
Death	149	3.7
Younger than 18 years old	49	1.2
Others*	111	2.7

* Inability to locomote due to a physical problem or illness, inability to answer the questionnaire by themselves, pregnant women, and interviewing interference by others.

To assess the built environment attributes, we created four different buffers around the residences of the cohort members of the ISA – Physical Activity and Environment as follows: a 500 m radial buffer, 1,000 m radial buffer, 500 m network buffer, and 1,000 m network buffer. Radial buffers were adopted in baseline studies associated with our study (Florindo *et al.* 2017, 2018, 2019). However, this method can be less accurate, especially in areas with poor street connectivity or natural or built barriers, such as rivers, lakes, or subway/railway lines, because it does not consider road systems. In contrast, the network buffer is closer to the actual environment available to pedestrians and cyclists once it considers the road network to be made, including the pedestrian networks, such as stairs and alleys (Sandalack *et al.* 2013). We adopted 500 and 1,000 m distances, for all buffers, because they are frequently used (Kirtlan *et al.* 2003, Frank *et al.* 2005, Rutt and Coleman 2005, Nelson *et al.* 2006, McCormack *et al.* 2006, Berke *et al.* 2007, Florindo *et al.* 2019) and represent distances that people can access by foot within 15 min (McCormack *et al.* 2006).

For each buffer around the participants' addresses, we calculated the combination of presence or absence of the built environment attribute in both periods studied and grouped them into four categories: negative maintenance (— —) = absence of attribute for both years (2015 and 2020); negative change (+ —) = present in 2015 and absent in 2020; positive change (— +) = absent in 2015 and present in 2020; positive maintenance (++) = present for both years.

All attributes were geocoded using ArcGIS Desktop version 10.8.1. To calculate the differences in built environment attributes, Stata MP 16.1, and SPSS 24.0 were used.

Results

Figure 1 shows population density by health administrative regions, inhabitants per square kilometer (1a), the four quartiles of census tracts' income (1b), and ISA – Physical Activity and Environment participants' geospatial location (1c) in the city of Sao Paulo. As shown in Figure 1(c), the sample is well distributed across the residential areas of the city. It is also important to highlight that the southern region is the least populated area, with 69.8% of the area covered by protected green regions and dams.

Population density is high in the downtown, east, and southeast administrative regions (Figure 1(a)). The income level is higher in the downtown and lower in the peripheral regions, mainly in the south and east (Figure 1(b)).

A total of 35.5% of the 2014/2015 sample remained in the second-wave telephone survey. The causes of sample loss were as follows in Table 3. Despite this high sample loss, it is important to highlight that the spatial pattern of home addresses across the city remained similar at baseline and follow-up (Figure 1(c)).

All built environment elements increased between 2015 and 2020 in Sao Paulo city (Table 4), with outdoor gyms (109.6%) and bike paths (67.7%) showing the greatest changes. All figures with maps that compare the built environment variables according to the six health administrative areas between 2015 and 2020 are shown in the supplementary materials (Figures S1 to S8).

After the population size saw a greater increase than the changes in some of the infrastructure, the built environment attributes adjusted per million inhabitants changed for the whole city (Table 4).

Table 5 shows the number of built environment facilities and their absolute differences between 2015 and 2020 according to the quartiles of census tract income. Additionally, Figure 2 shows the relative differences. It is clear to see the disproportionality of chances within and between the built environment attributes.

We observed a greater increase in public square and bike paths in the poorest regions than in the richest regions. However, attributes, such as public squares, bike paths, outdoor gyms, and large transportation stations, were found to be more abundant in the richest regions.

Figure 3 shows the built environment items in the home neighborhoods of the sample of adults in the ISA – Physical Activity and Environment between 2014/2015 and 2020/2021.

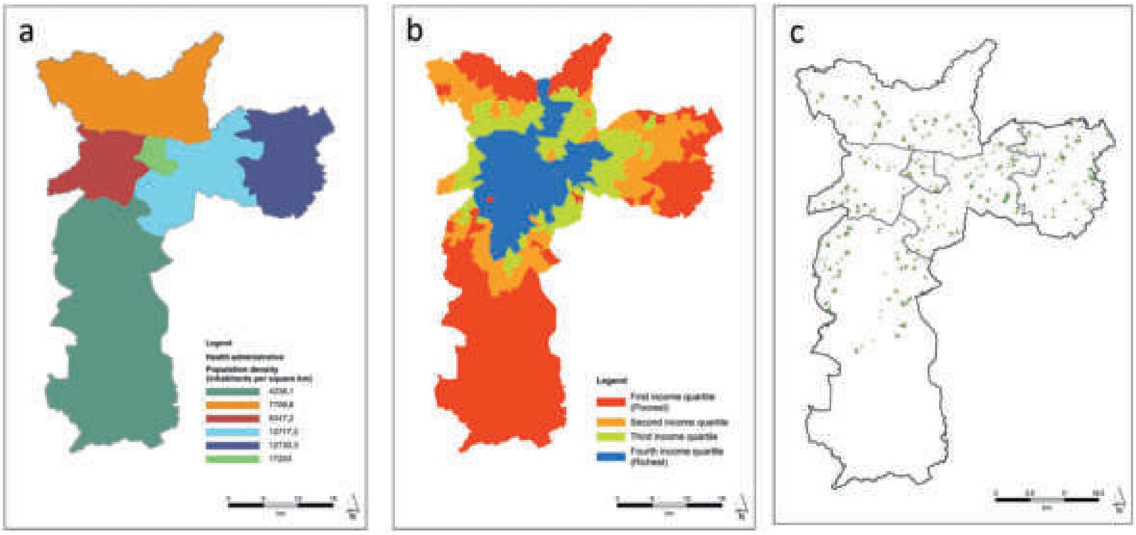

Figure 1. (a) population density of Sao Paulo, in inhabitants per square km, according to the six health administrative areas in 2020. (b) quartile of census tracts' income. (c) home address of sample (n = 1434) that was evaluated in the second wave in 2020/2021 of the ISA – physical activity and environment. All the figures were made using the software ArcGIS desktop version 10.8.1. Geographic coordinate systems SIRGAS 2000, UTM projection, fuse 23 South.

Table 4. Amount of built environment facilities, and their percentage difference between 2015 and 2020, adjusted per million inhabitants for Sao Paulo city, Brazil.

	Sao Paulo city			Sao Paulo city (adjusted per million of inhabitants)		
	2015	2020	% diff	2015	2020	% diff
Public squares (km^2)	10.30	11.20	8.74	0.89	0.94	6.10
Parks (km^2)	19.70	20.10	2.03	1.70	1.69	−0.44
Sport facilities	100	112	12.0	8.634	9.436	9.3
Community clubs	286	293	2.4	24.69	24.68	0.0
Outdoor gyms	311	652	109.6	26.85	54.93	104.6
Bike paths (km)	436.2	731.4	67.7	37.66	61.62	63.6
Train, subway stations and bus terminals	156	180	15.4	13.47	15.16	12.6
Primary health care units	457	470	2.8	39.46	39.6	0.4

% diff= Percentage difference between 2015 and 2020.

Table 5. Amount of built environment facilities and their absolute differences between 2015 and 2020, according to the quartiles of census tracts' income.

	Poorest			2nd quartile			3rd quartile			Richest		
	2015	2020	diff	2015	2020	diff	2015	2020	diff	2015	2020	diff
Public squares (km Malta *et al.* 2017)	0.84	1.01	0.17	2.34	2.79	0.45	3.27	3.44	0.17	3.86	3.96	0.09
Parks (km Malta *et al.* 2017)	6.6	6.7	0.15	4.99	5.00	0.01	1.57	1.57	0.00	6.04	6.27	0.23
Sport facilities	27	29	2	23	28	5	24	27	3	26	28	2
Community clubs	41	56	15	88	82	−6	113	115	2	43	40	−3
Outdoor gyms	55	116	61	83	176	93	107	221	114	66	139	73
Bike paths (km)	28.9	53.1	24.2	83.1	162.1	79.0	145.0	225.6	80.6	178.9	290.4	111.5
Train, subway stations and bus terminals	9	11	2	30	35	5	43	46	3	74	88	14
Primary health care units	149	155	6	144	147	3	108	111	3	56	57	1

diff= absolute difference between 2015 and 2020.

We detected a higher percentage of 'positive maintenance' or 'positive changes' status for the public squares, outdoor gyms, bike paths, and primary health care units. For example, considering the 500 m radial buffer, 78.8% of the sample had at least one public square inside the buffer in both years, while, for 4.3%, it was absent in 2015 and present in 2020.

Discussion

The results of this study showed that the number of built environment facilities for physical activity promotion in the city of Sao Paulo increased between 2015 and 2020. Areas such as public squares, sports facilities, outdoor gyms, and bike paths increased reaching regions with greater social inequalities and higher population density. However, we had a small increase in big green areas like parks. In addition, the sample from ISA-Physical Activity and Environment study had a substantial number of public squares, primary health care units, outdoor gyms, and bike paths up to 1,000 m from your homes but not parks and transportation stations.

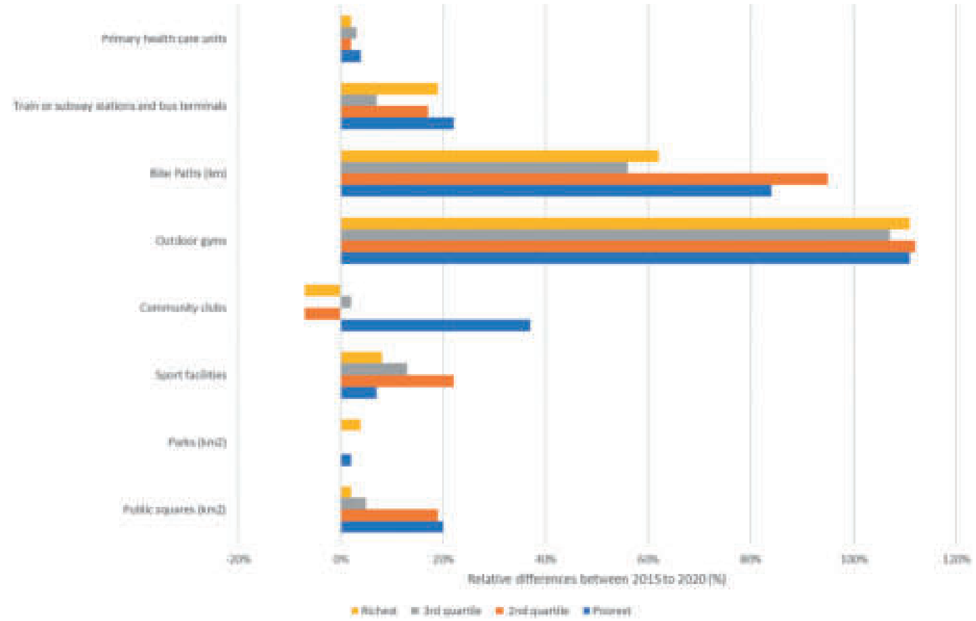

Figure 2. Relative differences of built environment facilities between 2015 and 2020, according to the quartiles of census tracts' income.

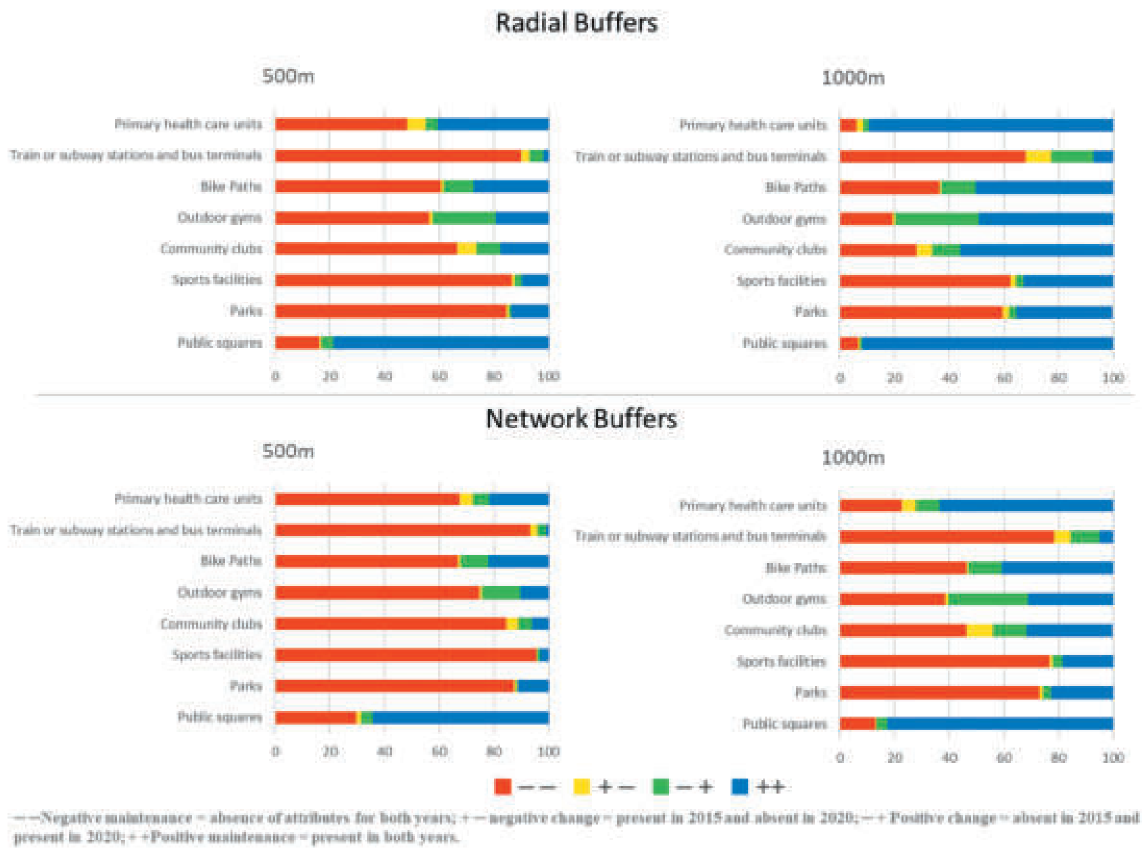

Figure 3. Percentage of the home address of adults of "ISA – physical activity and environment" (n = 1434), according to presence or absence of built environment facilities between 2015 and 2020, by type and size of buffers.

Access to and quality of green spaces have been associated with higher levels of leisure-time physical activity (Florindo *et al.* 2019, Helena *et al.* 2017). We found a substantial increase in the number of public squares in Sao Paulo city (8.7%) and in regions of low socioeconomic levels, but not parks (2.0%). In the last 5 years six new parks have been implemented: three in the southern region, two in the west, and one in the east. According to the New Master Plan, Sao Paulo must prioritize new parks. According to a recent study comparing 25 cities in 19 countries, 74.1% of city residents in high-income countries have access, <500 m walking distance, to large open public spaces with green areas larger than >1.5 hectares, compared to only 41.5% for cities in middle-income countries. For Sao Paulo city, this value is even discrepant – only 15.5%, showing the emerging necessity to invest in increasing the number of parks in Sao Paulo (Boeing *et al.* 2022). Green areas can have many benefits, not only for physical activity but also for improved air quality, mental health (Beyer *et al.* 2014), cognitive function, reduction of cardiovascular diseases, reduction of the prevalence of type 2 diabetes, and reduction of all causes of mortality (World Health Organization. Regional Office for Europe 2016). Additionally, the addition of green urban infrastructure can contribute to the direct and indirect achievement of Sustainable Development Goal targets by potentially impacting water management, flood reduction, carbon storage and removal, reduced energy use in buildings, air quality improvement, social benefits, ecological benefits, and human health and well-being benefits (Blicharska *et al.* 2019). Cerin and colleagues, studying more 11,615 adults living in 14 cities across ten countries, show that reduced distance to the parks is associated with more physical activity (Cerin *et al.* 2022).

An increased number of sports facilities was observed within the 5 years in the city of Sao Paulo, Brazil, mainly in 2nd income quartiles of regions. This is important for leisure-time physical activity promotion, because some recreational facilities include gyms, swimming pools, sports fields, track fields, and physical education professionals with free public classes (Van Cauwenberg *et al.* 2018). Furthermore, looking at the city as a whole city, the increase in community clubs was smaller than the increase in sports facilities (12.0% vs. 2.4%). When considering the income context, the poorest region was prioritized, with an increase of 37% in community clubs, that are important to support social organizations focused on promoting physical activity among people living nearby (World Health Organization 2018).

The outdoor gyms showed the largest increase in number between 2015 and 2020, at all levels of our analysis and in all income levels of regions. The effects of these structures on population physical activity levels are inconclusive, but there are some evidences that these facilities may improve physical activity, fitness, and other health-related outcomes (Jansson *et al.* 2019, Battistel *et al.* 2021). We found that in Sao Paulo city, outdoor gyms are located mainly near (less than 30 m from) the public squares (537 of the 652 outdoor gyms are inside this range), and future inferential analysis should consider this overlap. In this sense, it is necessary to better define what and where the outdoor gyms are, so that better comparative studies can be carried out between cities. For example, in the case of Sao Paulo, according to data from the Lancet Series, more than 70% of the population has access to open public spaces that also include squares. These results are closer to cities in high-income countries, such as Melbourne, Sydney, Cologne, Odense, Ghent, Ber, Lisbon, Barcelona and above cities in high-, middle- and low-income countries, such as Baltimore, Phoenix, Seattle, Hanoi, Chennai, Bangkok, Maiduguri, and Mexico.

Bike paths increased across the city 67.7%, mainly in the East (97.0%) and North (76.2%) regions, and in the poorest regions of the city (84% poorest quartile and 95% 2nd quartile). These facilities are related to leisure-time walking, running, and with bicycles for transportation (Florindo *et al.* 2017, 2018, 2019). This reflection was one of the most important results from policies like the New Master Plan and in the Urban Mobility Plan and can contribute to promote physical activity, with the decrease air pollution, and with road traffic safety (Salvo *et al.* 2021). In this aspect, we believe that Sao Paulo is in the right way, once making environments convenient and safe for cycling is crucial to achieve the equity, especially for those with low socio-economic status (Salvo *et al.* 2021). The city of Santiago (Chile), although presented a similar relative bicycling infrastructure increase, (62% from 2003 to 2019), did not addressed the equity question once the most bicycle lanes were concentrated in central region where middle- and upper-middle income groups live (Mora *et al.* 2021).

Within the 5 year time frame of this study, 24 new train/subway stations and bus terminals were created, mainly in the southeast and the richest regions (n = 14). Comparing Sao Paulo with other cities, more than 90% of the population has access to a public transport stop with regular service every 20 min or less, value higher than Australian cities and all cities in low- and middle-income countries (Boeing *et al.* 2022). Access to large public transit stations near residences is related to walking and cycling for transportation (Florindo *et al.* 2018, 2019, Hino *et al.* 2014). It is very important to continue to prioritize public transit across the city because it supports a type of physical activity that is very common and easy for most of the population and decreases car dependency (Nieuwenhuijsen 2020), mainly in South and East regions. In this sense, Kärmeniemibased and colleagues, based on a systematic review of longitudinal studies and natural experiments, show that proximate public transportation increases physical activity and reinforces the importance of investments in this kind of infrastructure (Kärmeniemi *et al.* 2018). Other factors, such as transport speed and service frequency are also stronger predictors of walking (Arundel *et al.* 2018), and they are also considered a policy target for Sao Paulo (Lowe *et al.* 2022).

We did not observe any changes in the number of primary health care units. However, we found that there are 470 units across the city, mainly in the eastern and southern regions. Many of these units have initiatives to promote physical activity implemented by physical education professionals and are, therefore, very important for leisure time and walking for transportation (Florindo *et al.* 2019, Helena *et al.* 2017, Gomes *et al.* 2014). For example, the most import program of physical activity promotion in Brazil is implemented in the Unified Public Health System Brazil ('Sistema Único de Saúde – SUS') with actions developed in primary health care units in Brazil (Programa Academia da Saúde 2011).

From the perspective of the participants, independent of the type and size of the buffers, more than 60% of the ISA-Physical Activity and Environment study had positive changes in the availability of public squares, primary health care units, outdoor gyms, and bike paths in the 1,000 buffers. However, the most of sample had low access to parks and transportation stations, trains, subway, and bus terminals. Thus, the next step is to investigate if, and how much, these environmental changes affect the people behavior, such as physical activity, and health, such as incidence of obesity, mental and cardiovascular diseases.

This study has some limitations. There was only a descriptive study that only quantified the facilities and did not evaluate their quality, which is also important for promoting physical activity. For example, some bike paths available in the GEOSAMPA library could be deteriorated or unusable. Parks and sports facilities can have equipment differing in quality. There could be errors in the outdoor gym numbers owing to the lack of data available in the GEOSAMPA library. We also found that some datasets (e.g. the free GEOSAMPA library) had considerable missing data (e.g. public squares). Missing data are not uncommon and have been demonstrated in studies from other countries (Withehead *et al.* 2021, Hooper *et al.* 2013, Boone *et al.* 2008). Fortunately, the data describing the built environments in our study were complete and robust. Finally, the estimated population and tract income was based on the last available census, in 2010, but adjusted to 2015 and 2020.

Conclusions

This paper shows important changes in built environment facilities for physical activity promotion in Sao Paulo city. Outdoor gyms (+109.6%), bike paths (+67.7%), train, subway stations, and bus terminals (+15.4%), and sports facilities (+12.0%) were the attributes that grew the most between 2015 and 2020. These facilities had increased in low socioeconomic areas and in higher population density places. However, there was a small increase of parks. For the sample of ISA-Physical Activity and Environment study, the results showed good changes (+60%) in the number of public squares, primary health care units, outdoor gyms, and bike paths from 1,000 m your residences. However, there was low access to parks and transportation stations.

We consider this monitoring important to verify whether policies such as the New Master Plan, Urban Mobility Plan, and Statute of Pedestrian are being executed effectively. In addition, this paper supports the important discussion of the inclusion of health goals and targets in planning policies, like increasing physical activity in leisure-time, walking, and cycling for transportation, and decreasing obesity and mental health problems according to healthy cities (Giles-Corti *et al.* 2016). In this sense, future research can investigate whether these changes and different built environments are associated with changes in health outcomes and use new indicators according to Urban Design, Transport and Health series (Giles-Corti *et al.* 2022). Finally, changes in the built environment for physical activity promotion are important because they support the Sao Paulo Declaration on Planetary Health (Myers *et al.* 2021) and will help to achieve sustainable development goals (United Nations Department of Economic and Social Affairs 2020) and to build a city that is better and fairer for people.

Highlights

- Outdoor gyms, bike paths, public transportation stations, sports facilities, and public squares increased over 5 years.
- The cohort sample was more exposed to public squares, outdoor gyms, bike paths, and primary health care units.
- Bike paths, public transportation stations, and public squares were more prevalent in high-income than low-income regions.

Authors' contributions

IPT and AAF conceived of the study. IPT, JPASB, and LVB contributed to the georeferencing of the built environment variables. IPT and AAF contributed to the descriptive analysis. IPT, AAF, JPASB, LVG, AAFH, PMN, DRA, SM, GT, and RSR contributed to the interpretation and writing of the results. IPT lead the writing. All authors contributed to the drafting and critical revision of the manuscript and approved the final version.

Disclosure statement

No potential conflict of interest was reported by the author(s)

Notes on contributor

The study encompasses an interdisciplinary research team specialized in physical activity epidemiology, nutritional epidemiology, georeferencing applied to health, statistics, agent-based modeling, public health policy and health economics, from the University of Sao Paulo (Brazil), other research institutions from the state of Sao Paulo, other

Brazilian states, Australia, United Kingdom, Portugal, and United States.

Funding

We received external funding from the Sao Paulo Research Foundation (FAPESP), Brazil (funding number 2017/17049–3 and 2020/01312-0). The content is solely the responsibility of the authors and does not necessarily represent the official views from FAPESP. Funders do not have any role in the execution of the study nor the interpretation or report of the results. IPT is receiving a research fellowship from the Minas Gerais State University. SM was supported by a University of Melbourne Faculty of Medicine, Dentistry and Health Sciences Research Fellowship. AAF is receiving a research fellowship from the Brazilian National Council for Scientific and Technological Development (CNPq) (grant 309301/2020-3). RSR was supported by the Centers for Disease Control and Prevention (number U48DP006395) and the Foundation for Barnes-Jewish Hospital. The findings and conclusions in this paper are those of the authors and do not necessarily represent the official positions of the Centers for Disease Control and Prevention.

ORCID

Inaian Pignatti Teixeira http://orcid.org/0000-0002-9723-4297

References

Arundel, J. et al., 2018. *Creating liveable cities in Australia: mapping urban policy implementation and evidence-based national liveability indicators - RMIT University*. Available from: https://researchrepository.rmit.edu.au/esploro/outputs/report/Creating-liveable-cities-in-Australia-Mapping/9921859005601341 [Accessed 5 September 2022].

Barnett, D.W., et al., 2017. Built environmental correlates of older adults' total physical activity and walking: a systematic review and meta-analysis. *The international journal of behavioral nutrition and physical activity*, 14, 1–24.

Battistel, J.A., et al., 2021. Perfil dos frequentadores e padrão de utilização das academias ao ar livre: revisão de escopo. *Revista Brasileira de Atividade Física & Saúde*, 26, 1–8.

Bauman, A.E., et al., 2012. Correlates of physical activity: why are some people physically active and others not? *Lancet*, 380, 258–271.

Berke, E.M., et al., 2007. Association of the built environment with physical activity and obesity in older persons. *American journal of public health*, 97 (3), 486–492.

Beyer, K.M.M., et al., 2014. Exposure to neighborhood green space and mental health: evidence from the survey of the health of wisconsin. *International journal of environmental research and public health*, 11, 3453–3472.

Blicharska, M., et al., 2019. Biodiversity's contributions to sustainable development. *Nature sustainability*, 212 (2), 1083–1093.

Boeing, G., et al., 2022. Urban design, transport, and health 3 using open data and open-source software to develop spatial indicators of urban design and transport features for achieving healthy and sustainable cities. *Lancet global health*, 10, e907–918.

Boone, J.E., et al., 2008. Validation of a GIS facilities database: quantification and implications of error. *Annals of epidemiology*, 18 (5), 371–377.

Brazil, 2021. *Vigilância de fatores de risco e proteção para doenças crônicas por inquérito telefônico*. Available from: https://www.gov.br/saude/pt-br/centrais-deconteudo/publicacoes/publicacoes-svs/vigitel/relatorio-vigitel-2020-original.pdf [Accessed 5 September 2022].

Brazil Programa Academia da Saúde, 2011. *Programa academia da Saúde*. Available from: https://aps.saude.gov.br/ape/academia [Accessed 5 September 2022].

Brownson, R.C., Newschaffer, C.J., and Ali-Abarghoui, F., 1997. Policy research for disease prevention: challenges and practical recommendations. *American journal of public health*, 87, 735.

Câmara, J.A., 2010. Plano diretor. In: S. Ferraz and A. A. Dallari, eds. *Estatuto da Cidade (Comentários à Lei federal 10.257/2001)*. 4th ed. São Paulo: Malheiros, 318–334.

Cauwenberg, J.V., et al., 2011. Relationship between the physical environment and physical activity in older adults: a systematic review. *Health & place*, 17 (2), 458–469.

Cerin, E., et al., 2022. Determining thresholds for spatial urban design and transport features that support walking to create healthy and sustainable cities: findings from the IPEN adult study. *Lancet global health*, 10, e895–906.

Cunningham, G.O. and Michael, Y.L., 2004. Concepts guiding the study of the impact of the built environment on physical activity for older adults: a review of the literature. *American journal of health promotion : AJHP*, 18, 435–443.

Duncan, M.J., Spence, J.C., and Mummery, W.K., 2005. Perceived environment and physical activity: a meta-analysis of selected environmental characteristics. *The international journal of behavioral nutrition and physical activity*, 2 (1), 1–9.

Edwards, P. & Tsouros, A.D., 2012. *A healthy city is an active city: a physical activity planning guide*. Copenhagen: WHO Regional Office for Europe. Available from: https://www.euro.who.int/__data/assets/pdf_file/0012/99975/E91883.pdf [Accessed 5 September 2022].

Florindo, A.A., et al., 2017. Public open spaces and leisure-time walking in Brazilian adults. *International journal of environmental research and public health*, 14 (6), 553.

Florindo, A.A., et al., 2018. Cycling for transportation in Sao Paulo city: associations with bike paths, train and subway stations. *International journal of environmental research and public health*, 15 (4), 562.

Florindo, A.A., et al., 2019. Walking for transportation and built environment in Sao Paulo city, Brazil. *Journal of transport and health*, 15, 100611.

Florindo, A.A., et al., 2021. Study protocol: health survey of Sao Paulo: iSA-physical activity and environment. *BMC public health*, 21, 283.

Frank, L.D., et al., 2005. Linking objectively measured physical activity with objectively measured urban form: findings from SMARTRAQ. *American journal of preventive medicine*, 28 (Suppl 2), 117–125.

Galán, I., et al., 2021. Small area influences on the individual unhealthy lifestyle behaviors: a multilevel analysis of discriminatory accuracy. *Health & place*, 67, 102506.

Giles-Corti, B., et al., 2016. City planning and population health: a global challenge. *Lancet*, 388, 2912–2924.

Giles-Corti, B., et al., 2022. What next? Expanding our view of city planning and global health, and implementing and monitoring evidence-informed policy. *Lancet global health*, 10, e919–926.
Gomes, G.A.O., et al., 2014. Characteristics of physical activity programs in the Brazilian primary health care system. *Cadernos de saude publica*, 30 (10), 2155–2168.
Helena, E., et al., 2017. Avaliação da efetividade de intervenções de promoção da atividade física no sistema único de Saúde. *Revista de saude publica*, 51, 1–12.
Hino, A.A., et al., 2014. Built environment and physical activity for transportation in adults from Curitiba, Brazil. *Journal of urban health: bulletin of the New York Academy of Medicine*, 91 (3), 446–462.
Hooper, P.L., et al., 2013. Measurement error in studies of the built environment: validating commercial data as objective measures of neighborhood destinations. *Journal of physical activity & health*, 10 (6), 792–804.
Humpel, N., et al., 2002. Environmental factors associated with adults' participation in physical activity: a review. *American journal of preventive medicine*, 22 (3), 188–199.
Instituto Brasileiro de Geografia e Estatistica – IBGE, 2020. *IBGE cidades*. Available from: https://cidades.ibge.gov.br/brasil/sp/sao-paulo/panorama [Accessed 30 November 2020].
Jacobs, J., et al., 2019. Variation in the physical activity environment according to area-level socio-economic position—a systematic review. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, 20, 686–700.
Jansson, A.K., et al., 2019. A systematic review of outdoor gym use: current evidence and future directions. *Journal of science and medicine in sport / sports medicine Australia*, 22, 1335–1343.
Jáuregui, A., et al., 2021. Scaling up urban infrastructure for physical activity in the COVID-19 pandemic and beyond. *Lancet*, 398 (10298), 370–372.
Kärmeniemi, M., et al., 2018. The built environment as a determinant of physical activity: a systematic review of longitudinal studies and natural experiments. *Annals of behavioral medicine : a publication of the society of behavioral medicine*, 52 (3), 239–251.
Kirtlan, K.A., et al., 2003. Environmental measures of physical activity supports: perception versus reality. *American journal of preventive medicine*, 24 (4), 323–331.
Lowe, M., et al., 2022. City planning policies to support health and sustainability: an international comparison of policy indicators for 25 cities. *Lancet global health*, 10, e882–894.
Malta, D.C., et al., 2017. Mortality due to noncommunicable diseases in Brazil, 1990 to 2015, according to estimates from the global burden of disease study. *Sao Paulo medical journal*, 135 (3), 213–221.
Malta, D.C., et al., 2020. Trends in mortality due to non-communicable diseases in the Brazilian adult population: national and subnational estimates and projections for 2030. *Population health metrics 2020*, 181 (18), 1–14.
Marques, E. and Saraiva, C., 2017. Urban integration or reconfigured inequalities? Analyzing housing precarity in São Paulo, Brazil. *Habitat international*, 69, 18–26.
McCormack, G.R., et al., 2006. The relationship between destination proximity, destination mix and physical activity behaviors. *Preventive medicine*, 46, 33–40.
Mora, R., Truffello, R., and Oyarzún, G., 2021. Equity and accessibility of cycling infrastructure: an analysis of Santiago de Chile. *Journal of transport geography*, 91, 102964.
Myers, S.S., Pivor, J.I., and Saraiva, A.M., 2021. The São Paulo declaration on planetary health. *Lancet*, 398 (10308), 1299.
Nelson, M.C., et al., 2006. Built and social environments associations with adolescent overweight and activity. *American journal of preventive medicine*, 31, 109–117.
Nieuwenhuijsen, M.J., 2020. Urban and transport planning pathways to carbon neutral, liveable and healthy cities; a review of the current evidence. *Environment international*, 140, 105661.
Nogueira, L.R., et al., 2018. Access to street markets and consumption of fruits and vegetables by adolescents living in São Paulo, Brazil. *International journal of environmental research and public health*, 15 (3), 517.
Oldenburg, B., Hardcastle, D.M., and Kok, G., 2008. Diffusion of innovations. *In*: K. Glanz, F.M. Lewis, and B.K. Rimer, eds. *Health behavior and health education: theory, research, and practice*. 4th ed. San Francisco: Jossey-Bass, 270–286.
Owen, N., et al., 2004. Understanding environmental influences on walking; review and research agenda. *American journal of preventive medicine*, 27 (1), 67–76.
Panter, J.R. and Jone, A., 2010. Attitudes and the environment as determinants of active travel in adults: what do and don't we know? *Journal of physical activity & health*, 7 (4), 551–561.
Prefeitura do Município de São Paulo, 2015. *Plano de mobilidade de São Paulo*. Available from: https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/chamadas/planmobsp_v072__1455546429.pdf [Accessed 17 Oct 2022].
Prefeitura do Município de São Paulo, 2020. *Pedestrian statute*. Available from: https://leismunicipais.com.br/a/sp/s/sao-paulo/decreto/2020/5967/59670/decreto-n-59670-2020-regulamenta-a-lei-n-16673-de-13-de-junho-de-2017-que-institui-o-estatuto-do-pedestre-no-municipio-de-sao-paulo [Accessed 5 September 2022].
Rutt, C.D. and Coleman, K.J., 2005. Examining the relationships among built environment, physical activity, and body mass index in El Paso, TX. *Preventive medicine*, 40 (6), 831–841.
Saelens, B.E. and Handy, S.L., 2008. Built environment correlates of walking: a review. *Medicine and science in sports and exercise*, 40, S550.
Salvo, D., et al., 2021. Physical activity promotion and the united nations sustainable development goals: building synergies to maximize impact. *Journal of physical activity and health*, 18, 1163–1180.
Sandalack, B.A., et al., 2013. Neighbourhood type and walkshed size. *Journal of urbanism*, 6 (3), 236–255.
São Paulo, 2014. *LEI Nº 16.050, DE 31 DE JULHO DE 2014*. Available from: http://legislacao.prefeitura.sp.gov.br/leis/lei-16050-de-31-de-julho-de-2014 [Accessed 5 September 2022].
São Paulo Secretaria Municipal da Saúde, 2015. *Aspectos metodológicos e produção de análises. Boletim ISA capital 2015*. Available from: https://www.prefeitura.sp.gov.br/cidade/secretarias/upload/saude/arquivos/publicacoes/ISA_2015_MA.pdf [Accessed 5 September 2022].
Schüle, S.A. and Bolte, G., 2015. Interactive and independent associations between the socioeconomic and objective built environment on the neighbourhood level and individual health: a systematic review of multilevel studies. *PLoS one*, 10, e0123456.
Sharp, G. and Kimbro, R.T., 2021. Neighborhood social environments, healthy resources, and adult diabetes: accounting for activity space exposures. *Health & place*, 67, 102473.

Silva, D.A.S., et al., 2020. Physical inactivity as a risk factor for all-cause mortality in Brazil (1990–2017). *Population health metrics 2020*, 181 (18), 1–9.

Smith, M., et al., 2017. Systematic literature review of built environment effects on physical activity and active transport – an update and new findings on health equity. *The international journal of behavioral nutrition and physical activity*, 141 (1), 1–27.

United Nations Department of Economic and Social Affairs, 2020. *The sustainable development goals report 2020*. New York: United Nations. Available from: https://www.un-ilibrary.org/content/books/9789210049603/read [Accessed 5 September 2022].

Van Cauwenberg, J., et al., 2018. Relationships between neighbourhood physical environmental attributes and older adults' leisure-time physical activity: a systematic review and meta-analysis. *Sports medicine*, 48, 1635–1660.

Wendel-Vos, W., et al., 2007. Potential environmental determinants of physical activity in adults: a systematic review. *Obesity reviews : an official journal of the International Association for the Study of Obesity*, 8 (5), 425–440.

Withehead, J., et al., 2021. Improving spatial data in health geographics: a practical approach for testing data to measure children's physical activity and food environments using google street view. *International journal of health geographics*, 20, 37.

World Health Organization. *Noncommunicable diseases and physical inactivity*. Available from: http://www.emro.who.int/noncommunicable-diseases/causes/physical-inactivity.html [Accessed 5 September 2022].

World Health Organization, 2018. *Global action plan on physical activity 2018–2030: more active people for a healthier world*. World Health Organization. Available from: https://apps.who.int/iris/handle/10665/272722 [Accessed 5 September 2022].

World Health Organization, 2021. *Noncommunicable diseases*. Available from: https://www.who.int/news-room/fact-sheets/detail/noncommunicable-diseases [Accessed 5 September 2022].

World Health Organization Regional Office for Europe, 2016. *Urban green spaces and health*. Available from: https://apps.who.int/iris/handle/10665/345751 [Accessed 5 September 2022].