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Associations of neighborhood socioeconomic, natural and built environmental characteristics with a 13-year trajectory of non-work physical activity among civil servants in Rio de Janeiro, Brazil: The Pro-Saude Study

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ABSTRACT

Positive influences of natural and built environment characteristics on human physical activity have been observed mainly in high-income countries, but mixed results exist. We explored these relationships in Rio de Janeiro, Brazil, where exuberant nature coexists with high levels of social inequality and urban violence. Data originated from questionnaires self-administered by 1731 civil servants at university campuses who participated in 4 waves (1999, 2001, 2007, 2012) of a longitudinal study, and had their residential addresses geocoded. In multinomial regression models, adjusted for individual sociodemographic characteristics, mutually adjusted associations were estimated between 13-year trajectories of non-work physical activity and 8 contextual variables: distances from waterfronts, cycle paths, outdoor gym equipment, and squares; 2 indicators of exposure to greenness (a vegetation index - NDVI - derived from satellite images, and trees close to home); an indicator of walkability (street density), and neighborhood average income. Compared to participants living in the upper quartile of distance to waterfronts, those living in its lowest quartile had 2.6-fold higher odds (aOR: 2.62, 95% CI: 1.37–5.01) of reporting non-work PA in all 4 study waves. Similar results were observed in relation to distance to cycle paths; no independent associations were observed with other natural and built environment variables.

1. Introduction

Physical inactivity, increasingly recognized as a global pandemic, is a leading risk factor for noncommunicable diseases. The World Health Organization member states have agreed to reduce it by 10% by 2025 (WHO, 2013); despite existing efforts, however, evidence of improvements in prevalence is still scarce, and national physical activity policies are operational in only 56% of countries. In low- and middle-income countries (LMIC) physical inactivity is higher in urban settings (Sallis et al., 2016a, 2016b), which is of concern since the projected world population growth is expected to be concentrated in LMIC cities (UN, 2018).

Physical inactivity is not the consequence of individual attributes and choices alone; rather, it is also associated with characteristics of the built environment (e.g. Popkin et al., 2005; Foster et al., 2008; Sallis and Glanz, 2009; Renalds et al., 2010; McCormack et al., 2011; Bancroft et al., 2015; Sallis et al., 2016a, 2016b). Evidence is still mixed, but in general, studies conducted in high-income countries, such as the USA, Canada, Australia, and countries in Western Europe, tend to revealed that characteristics of urban space influence physical activity participation. Higher levels are observed in regions that have interconnected streets, which facilitate access to services, parks and recreational areas (Bauman, 2012; Heath, 2006; Sallis et al., 2016a, 2016b). Perceived safety and better traffic conditions, besides the presence of sidewalks, adequate urban street lighting, cycle paths, trails, green space and aesthetic landscapes have been also associated with physical activity (Bedimo-Rung, 2005; Pereira et al., 2012; McMorris et al., 2015). More specifically, with regard to green spaces and parks, several studies showed that physical activity is associated with access and ease for undertaking physical activity, low or zero cost, contact with nature, low

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air pollution, and sharing space with other physically active individuals (Bedimo-Rung, 2005; Nieuwenhuijsen et al., 2017).

Sallis et al. (2016a, 2016b) observed similar results in associations between the urban environment and leisure-time physical activity in 14 cities of middle-to-high income countries. Despite advances in knowledge, however, the vast majority of studies focused on high-income countries and fail to encompass a broader variety of urban environments. In addition, a large proportion of studies are based on measures of residents´ perceptions of the urban spaces in which they live, and do not consider the objective characteristics of those spaces (Sallis et al., 2016a, 2016b). Much inconsistency of results remain: Lachowycz and Jones (2011) observed that among studies examining the relationships between access-related measures of local green spaces and physical activity, only 40% found direct associations. In contrast, in a systematic review, Fong et al. (2018) found strong evidence about the positive role of exposure to greenness on levels of physical activity

In Brazil, classified by the World Bank as an upper middle-income country, (https://data.worldbank.org/country), there was an annual increase of 1.9% between 2006 and 2012 in self-reported leisure-time physical activity in capital cities; nonetheless, 48% of Brazilians living in those cities reported physical inactivity, more frequent among women (52%) than men (42%), and among older and less educated individuals (Mielke et al., 2014). A review by Bauman (2012) indicated the growth of related research in Brazil, mostly limited on subjective perceptions; moreover, results were inconsistent among those incorporating objective measures. (Hino et al., 2011; Reis et al., 2013).

To our knowledge, no such investigation has been conducted in Rio de Janeiro, Brazil´s second-largest city (1204 km^2), with a population of 6,5 million inhabitants (IBGE, 2010). Rio's exuberant nature includes a world-famous coastline, and plenty of other public open spaces, in principle favouring the adoption of healthy lifestyles, particularly physical activity. However, access and utilization of such spaces have been hindered by deeply rooted social and racial inequalities, as well as by pervasive urban violence.

From the mid-18th century until 1960, Rio was Brazil's capital city. After Brasilia was inaugurated, its participation in the national economy gradually declined, but still remained a highly influential political and cultural hub. Following the 1964 civil-military coup d'état, repression of leaderships and institutions opposing the regime was particularly fierce in Rio, opening political spaces for clientelistic groups to hold local power (Osorio and Versiani, 2016). Among other consequences of those historical, socioeconomic and political processes, in combination with unique geographical features, 22% of the city population ended up living in informal settlements (compared to 6% nationwide), mostly slums. During the last decade, population in those settlements grew 19%, in contrast with a 5% growth elsewhere in the city (IBGE, 2011). Slum dwellers have less access to adequate water and sanitation, average income is less than one third of other areas, and their life expectancy is much lower (Szwarcwald et al., 2011). Differently from the territorial distribution of poorer neighborhoods in other regions, in Rio those areas are dispersed (Snyder et al., 2014), including multinucleated "heat islands" (Peres, 2018).

In recent years, Rio has been under additional and complex territorial transformations, causing changes in its natural and built environment associated with multi-billion investments in infrastructures for several mega sporting events (2007 Pan American Games, 2014 World Cup, 2016 Olympics). Critics argue (e.g. Gaffney, 2010; Sanchez and Broudehoux, 2013) that a coalition of politicians and private entrepreneurs imposed temporary regimes of extra-legal governance that transformed Rio social space. Finally, escalating drug-related gang violence (Perlman, 2006) strongly contributes to the deterioration of Rio's population quality of life, thus negatively affecting health and health-related behaviours such as physical activity.

Investigating the experiences of a population exposed to such complex environment may contribute to the improve the understanding of the role of contextual determinants of physical activity. The objective of this study was to estimate associations of neighborhood socioeconomic, natural and built environmental characteristics with a 13-year trajectory of non-work physical activity among civil servants living in the city of Rio de Janeiro, Brazil.

2. Materials and methods

2.1. Study design and population

The longitudinal Pro-Saude study focuses primarily on social and psychosocial determinants of health and health-related behaviours of civil servants at several campuses of a university in the State of Rio de Janeiro, Brazil. All non-faculty administrative and technical employees except those relocated to another institution or who were on a non-health leave were eligible and invited to participate.

Data were collected using self-administered multidimensional questionnaires applied close to participants' workplaces by trained personnel. Methods were employed that ensured the quality of the information and data collection and processing (e.g., Chor et al., 2003; Faerstein et al., 2005).

The current analyses drew on data collected from 1731 individuals living in the Municipality of Rio de Janeiro (80% of total), who participated in all four waves of data collection (1999, 2001, 2007, 2012), and who had address information that could be geocoded, provided information on non-work physical activity (PA) and were not prevented from performing usual activities for health reasons.

2.1.1. Outcome variable

A variable was created to jointly represent the study participants' longitudinal trajectory of self-reported non-work physical activity (PA), assessed across the 4 study waves by dichotomous responses (yes vs. no) to the same question:*"In the past two weeks, have you done any physical activity to improve your health, physical condition or for aesthetic or leisure purposes?"*. In a pilot study involving 89 temporary civil servants at the same university campuses, the estimated bias-adjusted kappa coefficient (Byrt et al., 1993) was 0.95 (95% CI 0.98–1.00) for the test-retest dichotomous responses to the question. For analytic purposes, the PA longitudinal trajectory was classified into three outcome categories: No PA in all 4 study waves; PA in 1, 2 or 3 study waves, and PA in all 4 study waves.

Participants' sociodemographic characteristics (individual independent variables) were assessed in the first study wave: sex (male, female); age in years (categorized into < 40, 40–49, 50–59,60 + years); skin color/race (white, mixed race, black, other); education (elementary or less, high school, college or more); family income *per capita* in monthly minimum wages (MW, categorized into < 3 MW, 3–6 MW, > 6 MW); marital status (never married, married, separated/divorced, widowed).

Characteristics of the natural and built environment surrounding participants' homes, as well as their neighborhood average income were included in the study as contextual independent variables: First, participants´ residential addresses were geocoded using the georeferencing function of the Application Programming Interface – API of Google Maps. The API yielded the latitude and longitude of reported addresses using the Google Maps database. Subsequently, contextual variables were obtained from 3 different sources, as follows:

a) *Digital maps databases provided by Instituto Pereira Passos (IPP, Rio de Janeiro Municipality)*:

- Proximity to waterfronts, cycle paths, outdoor gym equipment, and squares: Euclidean distances (in meters) from residences;
- Street density: an estimate of walkability, this indicator considered a circular buffer of 800 m centred at participants´ homes, equivalent to a 10-min walk, suggested as maximum walking distance for a pedestrian-friendly environment (Gori et al., 2014), being the sum

of light traffic streets´ lengths divided by the buffer area. It was restricted to local and collector streets, responsible for the distribution of internal traffic to neighborhoods, thus excluding highways and heavy traffic streets.

b) *2010 Brazilian Census tracts (median values of 206 households and 592 inhabitants per tract):*

- Neighborhood average monthly income: collected per census tract by the Census Bureau (IBGE), was calculated based on the spatial moving average among adjacent tracts, so as to smooth random fluctuations;
- Greenness 1: Presence of trees close to home: The 2010 Census fieldwork included a visual inspection of the presence of tree linings close to residences; the variable, aggregated by census tracts, indicates the proportion $(0-1)$ of households close to trees.

c) *LandSat 4–5 TM set of the United States Geological Survey (USGS):*

- Greenness 2: Exposure to greenness was also estimated by the Normalized Difference Vegetation Index – NDVI. Satellite imagery was obtained from the LandSat 4–5 TM set of the USGS, accurate to 30 m. Plants produce a pattern of low reflectance of visible light waves and high reflectance of near-infrared; NDVI is calculated as the difference between the two wavelengths divided by their sum. The index measures the concentration of vegetation cover of a region, ranging from -1 to 1, with typical values lying between 0.1 and 0.7. Negative values indicate the presence of ice, water or snow, and values close to 0.7 indicate dense vegetation (Weier and Herring, 2000; Gascon et al., 2015). We calculated the average NDVI of eight selected images produced between 2010 and 2012 with up to 10% cloud. The exposure of each participant was measured using the mean NDVI within 800-meter buffer zones of participants´ residences.

Contextual variables were tested for multicollinearity, and the variance inflation factor (VIF) was consistently estimated as < 2.

2.2. Data analysis

Frequencies of strata of independent variables were calculated, and bivariate analyses were conducted to estimate frequencies of the three outcome categories for each of those strata.

In multinomial regression models, odds ratios (OR) and 95% confidence intervals (95%CI) were estimated for categories of non-work physical activity according to contextual variables of participants' area of residence. ORs were first adjusted for individual variables (model 1); in model 2 individual and contextual variables were mutually adjusted, and final model 3 includes mutually adjusted contextual variables if associated with the outcome (i.e. with 95% confidence intervals not overlapping unity in model 2) in addition to individual variables.

All analyses were carried out using the R 3.3.3 software program.

The study was approved by the Research Ethics Committee of the Institute of Social Medicine, State University of Rio de Janeiro (CAAE 0041.0.259.000-11); all participants signed informed consent.

3. Results

The current study included a relatively diverse population in sociodemographic aspects, predominantly married women in the 40–59 age range, with high school education or more, but lower family income per capita (Table 1).

Most participants reported non-work physical activity (PA) during the previous 2 weeks in 1, 2 or 3 study waves. White males aged 40–59 years, with higher educational level and higher family income per capita, more frequently reported PA in all 4 study waves. In contrast, no PA in all 4 study waves was more likely to be reported by black females of all ages, with lower educational level and lower family income *per capita* (Table 1).

With respect to the contextual characteristics of residential neighborhoods, PA in all 4 study waves was reported more frequently by individuals who lived in areas with higher average income *per capita*, closer to waterfronts and cycle paths, and had higher exposure to greenness (presence of trees close to home, and higher NDVI), and lower street density. No such pattern was observed in relation to proximity to outdoors gym equipment or squares (Table 1).

After adjusting for individual variables in multinomial regression (Table 2, model 1) the associations between non-work PA and contextual variables, a similar pattern persisted. In model 2, where individual and contextual variables were mutually adjusted, higher odds of non-work PA were also estimated, albeit weakened, for proximity to waterfronts and cycle paths, and for those living in neighborhoods with higher average income. No associations persisted with exposure do greenness (trees, NDVI) or street density, and in relation to proximity to squares and outdoor gym equipment.

In the final model (model 3), a similar picture was still observed: compared to participants living in the upper quartile of proximity (more distant) to waterfronts, those living in its lowest quartile (i.e. closer to waterfronts) had 2.6 higher adjusted odds (aOR: 2.62, 95% CI: 1.37–5.01) of reporting non-work PA in all 4 study waves. Similarly, most individuals who lived closer to cycle paths were more likely to report this pattern; however, increased odds were restricted to those in second and third quartiles of proximity, respectively, aOR: 2.89, 95% CI:1.64–5.07 and aOR: 1.86, 95% CI: 1.06–3.25). An independent association persisted with neighborhood average income, limited to the intermediate category (reported in 1–3 study waves) of non-work PA (aOR: 1.85, 95% CI: 1.10–3.11).

Final results were submitted to several sensitivity analyses, by further adjustments for season of the year (spring-summer vs. fall-winter) at the time of data collection and for time of residence in the same address (as a continuous variable, in years), with virtually no changes in estimates. Alternative buffer zones of participants´ residences were tested where applicable, without changing the results observed with the 800-meter buffer. Finally, Moran's index (Moran, 1950) of models' residuals did not show evidence of spatial autocorrelation among contextual variables.

4. Discussion

In our study of Rio de Janeiro civil servants, a 13-year longitudinal trajectory of non-work physical activity (PA) was associated with some (but not with others) contextual characteristics of participants' residential area, independently of several individual sociodemographic characteristics. Higher reported PA was observed among residents living closer to waterfronts (seafront and lakesides) or cycle paths. These associations persisted after adjusting for individual characteristics and for average income of the areas of residence.

In agreement with our findings, other studies have also reported that the presence and condition of cycle paths are important contextual correlates of physical activity (Sallis, 2009; Schulz, 2013; Hirsch et al., 2014; Eichinger, 2015; Silva et al., 2017). With regard to the waterfront, associations of PA with proximity of residences to the coast have been also observed by several authors (for example, Humpel et al., 2004; Edwards et al., 2014, Silva et al., 2017). In relation to greenness spaces, we did not observe the associations of interest; this is still a relatively recent area of scientific interest, and conflicting results are more frequent, probably due to the lack of agreed definitions and procedures.

The main strength of our study was the incorporation of the longitudinal trajectory of PA over 13 years; however the possibility of reverse causality cannot be entirely discarded, because physically active individuals may have chosen their location of residence for its ease of

Table 1
Frequency of non-work physical activity (PA) categories across a 13-year trajectory[a] according to individual sociodemographic characteristics and contextual (socioeconomic, natural and built environment) characteristics among civil servants in Rio de Janeiro, Brazil. Pro-Saude Study, 1999–2012.

Variables	N	No PA in all 4 waves		PA in 1, 2 or 3 waves		PA in all 4 waves	
		N	%	N	%	N	%
Sex							
Male	701	139	19.8	432	61.6	130	18.5
Female	1030	231	22.4	684	66.4	115	11.2
Age (years)							
< 40	82	19	23.2	56	68.3	7	8.5
40–49	609	131	21.5	390	64.0	88	14.4
50–59	724	149	20.6	466	64.4	109	15.1
> 59	316	71	22.5	204	64.6	41	13.0
Color/race							
White	867	159	18.3	570	65.7	138	15.9
Mixed	547	132	24.1	347	63.4	68	12.4
Black	276	72	26.1	175	63.4	29	10.5
Other	22	5	22.7	15	68.2	2	9.1
Educational level							
College or more	950	171	18.0	622	65.5	157	16.5
High school	572	146	25.5	353	61.7	73	12.8
Elementary or less	197	50	25.4	135	68.5	12	6.1
Family income *per capita* (minimum wage - MW)							
> 6 MW	200	24	12.0	127	63.5	49	24.5
3–6 MW	568	106	18.7	372	65.5	90	15.8
< 3 MW	948	235	24.8	608	64.1	105	11.1
Marital status							
Never married	254	67	26.4	154	60.6	33	13.0
Married	1054	206	19.5	696	66.0	152	14.4
Separated/divorced	310	70	22.6	195	62.9	45	14.5
Widowed	102	25	24.5	64	62.7	13	12.7
Proximity to waterfront (meters, quartiles)							
≥ 12.727.61	433	126	29.1	267	61.7	40	9.2
9.038.81 – 12.727.60	432	105	24.3	290	67.1	37	8.6
5.047.21 – 9.038.80	433	76	17.6	300	69.3	57	13.2
≥ 5.047.20	433	63	14.5	259	59.8	111	25.6
Proximity to cycle paths (meters, quartiles)							
1.199.29 – 8.736.00	433	118	27.3	285	65.8	30	6.9
627.74 – 1.199.28	432	95	22.0	279	64.6	58	13.4
256.51 – 627.73	433	75	17.3	275	63.5	83	19.2
0.13 – 256.50	433	82	18.9	277	64.0	74	17.1
Neighborhood average monthly income (US$, quartiles)							
≤ 786.95	433	126	29.1	261	60.3	46	10.6
789.96–1189.36	435	108	24.8	292	67.1	35	8.0
1189.37–1996.82	430	83	19.3	285	66.3	62	14.4
≥ 1996.83	433	53	12.2	278	64.2	102	23.6
Normalized Difference Vegetation Index (NDVI, quartiles)							
≤ 0.06	433	98	22.6	288	66.5	47	10.9
0.07–0.10	433	91	21.0	281	64.9	61	14.1
0.11–0.16	432	101	23.4	270	62.5	61	14.1
≥ 0.17	433	80	18.5	277	64.0	76	17.6
Presence of trees close to home (% of households, quartiles)							
≤ 0.67	433	112	25.9	270	62.4	51	11.8
0.68–0.85	433	95	21.9	282	65.1	56	12.9
0.85–0.96	433	101	23.3	282	65.1	50	11.5
≥ 0.97	432	62	14.4	282	65.3	88	20.4
Proximity to squares (meters, quartiles)							
≥ 301.6	432	97	22.5	279	64.6	56	13.0
205.8–301.5	433	99	22.9	265	61.2	69	15.9
126.7–205.7	433	76	17.6	295	68.1	62	14.3
≤ 126.6	433	98	22.6	277	64.0	58	13.4
Street density (m/km^2, quartiles)							
≤ 12.01	434	82	18.9	277	63.8	75	17.3
12.02–14.22	436	93	21.3	275	63.1	68	15.6
14.23–16.51	428	84	19.6	295	68.9	49	11.4
≥ 16.50	433	111	25.6	269	62.1	53	12.2
Proximity to outdoor gym equipment (meters, quartiles)							
≥ 1176.6	433	95	21.9	275	63.5	63	14.5
717.9–1176.5	432	102	23.6	274	63.4	56	13.0
437.9–717.8	433	87	20.1	287	66.3	59	13.6
≤ 437.8	433	86	19.9	280	64.7	67	15.5

[a] 13-year trajectory based on self-reported non-work physical activity (PA) across 4 study waves of data collection: 1999, 2001, 2006, 2012.

Table 2

Associations (adjusted ORs and 95% confidence intervals) of neighborhood socioeconomic, natural and built environment characteristics with 13-year trajectory[a] of non-work physical activity (PA) categories[b] among civil servants in Rio de Janeiro, Brazil. Pro-Saude Study, 1999–2012.

	Model 1*				Model 2**				Model 3***			
	PA in 1, 2 or 3 study waves		PA in all 4 study waves		PA in 1, 2 or 3 study waves		PA in all 4 study waves		PA in 1, 2 or 3 study waves		PA in all 4 study waves	
	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)	OR	(95% CI)
Proximity to waterfront (meters, quartiles)												
≥ 12.727.61	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–
9.038.81 – 12.727.60	1.25	(0.91–1.71)	1.05	(0.61–1.81)	1.12	(0.78–1.59)	0.89	(0.49–1.63)	1.15	(0.83–1.60)	0.96	(0.54–1.71)
5.047.21 – 9.038.80	1.66	(1.17–2.35)	1.84	(1.08–3.14)	1.25	(0.82–1.91)	1.21	(0.63–2.33)	1.31	(0.87–1.96)	1.32	(0.70–2.49)
≤ 5.047.20	1.65	(1.14–2.40)	4.05	(2.41–6.81)	1.13	(0.70–1.85)	2.46	(1.22–4.93)	1.21	(0.77–1.91)	2.62	(1.37–5.01)
Proximity to cycle paths (meters, quartiles)												
1.199.29 – 8.736.00	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–
627.74 – 1.199.28	1.16	(0.84–1.60)	2.22	(1.28–3.82)	1.06	(0.75–1.49)	1.86	(1.05–3.32)	1.04	(0.75–1.45)	1.86	(1.06–3.25)
256.51 – 627.73	1.47	(1.04–2.08)	3.98	(2.32–6.82)	1.26	(0.87–1.82)	2.96	(1.67–5.27)	1.26	(0.88–1.80)	2.89	(1.64–5.07)
0.13 – 256.50	1.23	(0.87–1.73)	2.76	(1.60–4.74)	0.99	(0.68–1.44)	1.63	(0.90–2.98)	1.00	(0.69–1.44)	1.60	(0.89–2.87)
Neighborhood average income (US$, quartiles)												
≤ 786.95	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–	1.00	–
786.96–1189.36	1.30	(0.94–1.79)	0.76	(0.44–1.30)	1.24	(0.87–1.78)	0.67	(0.36–1.23)	1.21	(0.87–1.69)	0.64	(0.36–1.12)
1189.37–1996.82	1.55	(1.09–2.19)	1.61	(0.96–2.71)	1.39	(0.87–2.22)	1.17	(0.57–2.38)	1.31	(0.88–1.96)	1.06	(0.57–1.95)
≥ 1996.83	2.20	(1.45–3.35)	3.46	(1.96–6.09)	1.98	(1.09–3.60)	1.52	(0.65–3.56)	1.85	(1.10–3.11)	1.46	(0.71–2.99)
Normalized Difference Vegetation Index (NDVI) (quartiles)												
≤ 0.06	1.00		1.00		1.00		1.00		–		–	
0.07–0.10	0.97	(0.70–1.36)	1.20	(0.73–1.97)	0.95	(0.67–1.34)	0.95	(0.57–1.61)	–		–	
0.11–0.16	0.88	(0.63–1.22)	1.16	(0.71–1.88)	0.82	(0.56–1.20)	0.68	(0.39–1.20)	–		–	
≥ 0.17	1.17	(0.83–1.66)	1.86	(1.14–3.03)	1.01	(0.63–1.61)	0.85	(0.44–1.65)	–		–	
Presence of trees close to house (% of households, quartiles)												
≤ 0.67	1.00	–	1.00	–	1.00	–	1.00	–	–		–	
0.68–0.85	1.10	(0.79–1.54)	1.00	(0.60–1.64)	0.95	(0.66–1.37)	1.00	(0.57–1.76)	–		–	
0.86–0.96	0.98	(0.70–1.37)	0.82	(0.49–1.36)	0.76	(0.51–1.13)	0.65	(0.35–1.21)	–		–	
≥ 0.97	1.50	(1.02–2.20)	1.99	(1.18–3.36)	1.05	(0.65–1.68)	1.22	(0.62–2.40)	–		–	
Proximity to squares (meters, quartiles)												
≥ 301.6	1.00	–	1.00	–	1.00	–	1.00	–	–		–	
205.8–301.5	0.94	(0.67–1.31)	1.07	(0.67–1.71)	0.94	(0.67–1.33)	1.06	(0.65–1.72)	–		–	
126.7–205.7	1.35	(0.95–1.90)	1.29	(0.80–2.10)	1.42	(1.00–2.04)	1.38	(0.83–2.29)	–		–	
≤ 126.6	0.99	(0.71–1.38)	0.98	(0.61–1.58)	1.10	(0.77–1.57)	1.05	(0.63–1.76)	–		–	
Street density (meters/km2, quartiles)												
≤ 12.01	1.00	–	1.00	–	1.00	–	1.00	–	–		–	
12.02–14.22	0.88	(0.62–1.25)	0.84	(0.53–1.34)	0.93	(0.63–1.36)	0.97	(0.58–1.62)	–		–	
14.23–16.50	1.02	(0.72–1.46)	0.68	(0.42–1.11)	1.08	(0.71–1.65)	0.92	(0.51–1.64)	–		–	
≥ 16.50	0.74	(0.53–1.04)	0.57	(0.35–0.91)	0.78	(0.51–1.20)	0.71	(0.38–1.31)	–		–	
Proximity to outdoor gym equipment (meters, quartiles)												
≥ 1176.6	1.00	–	1.00	–	1.00	–	1.00	–	–		–	
717.9–1176.5	0.88	(0.63–1.22)	0.79	(0.49–1.27)	0.85	(0.59–1.23)	0.80	(0.48–1.36)	–		–	
437.9–717.8	1.02	(0.73–1.44)	0.83	(0.51–1.34)	0.94	(0.64–1.38)	0.72	(0.41–1.25)	–		–	
≤ 437.8	1.01	(0.71–1.42)	0.95	(0.59–1.53)	0.94	(0.63–1.39)	0.79	(0.46–1.36)	–		–	

• Model 1 - adjusted for sex, skin color/race, education, income.

** Model 2 - adjusted for sex, skin color/race, education, income, neighborhood contextual variables.

*** Model 3 - adjusted for sex, skin color/race, education, income, neighborhood contextual variables with statistically significant associations with outcome in model 2.

[a] 13-year trajectory based on self-reported non-work physical activity (PA) across 4 study waves of data collection: 1999, 2001, 2006, 2012.

[b] reference category in multinomial regression: absence of non-work physical activity (PA) across 4 study waves.

access to environments favourable for non-work physical activity.

Another strength was the use of objective measurements of several characteristics of the natural and built environment, instead of limiting to individuals' self-perception. Also, in the absence of a standardized definition of neighborhood, whose spatial limitations need to be flexible depending on the event to be investigated (Diez Roux et al., 2016), sensitivity analyses were performed with different buffer sizes surrounding participants´homes (400 m, 800 m, 1200 m and 1600 m) when analysing NDVI, as carried out by James et al. (2016). No differences were found in associations between PA and green space density for buffer size, strengthening the findings of the study.

An important limitation was the assessment of physical activity based on a single item, with no inclusion of information on relevant characteristics of PA such as type, frequency, and duration, and whether performed indoors or outdoors.

This important area of research faces complex conceptual and methodological challenges, as outlined by Koohsari et al. (2015), such as expanding definitions of public open space; using longitudinal and experimental study designs where possible to strengthen causal inference; exploring public open space exposures in non-residential contexts; using multiple measures of proximity to public open space (for example, multiple public open space versus single nearest public open space; topological versus metric measures of proximity). The development of multiple measures of quality of public open space should be a priority, especially considering the need for more evidence from LMICs. Interactions among contextual determinants and between individual and contextual characteristics might also bring inferential advances. Not least important, analysing changes in neighborhood characteristics in conjunction with changes in PA would greatly refine longitudinal approaches.

It is well established that regular physical activity has a protective role beyond noncommunicable conditions such as hypertension, obesity, diabetes, heart disease, stroke, and breast and colon cancer. The WHO Global Action Plan on Physical Activity 2018–2030 (WHO, 2018) appropriately states that investing in policies to promote walking, cycling, sport, active recreation and play can contribute directly to achieving many of the 2030 Sustainable Development Goals (SDGs). Policy actions on physical activity have multiplicative health, social and economic benefits, and will directly contribute to achieving SDG3 (good health and well-being), as well as other Goals including SDG2 (ending all forms of malnutrition); SDG4 (quality education); SDG5 (gender equality); SDG8 (decent work and economic growth), SDG9 (industry, innovation and infrastructure); SDG10 (reduced inequalities); SDG11 (sustainable cities and communities); SDG12 (responsible production and consumption); SDG13 (climate action); SDG15 (life on land); SDG16 (peace, justice and strong institutions) and SDG17 (partnerships).

Historically, public health and urban planning emerged with the common goal of preventing urban outbreaks of infectious diseases. In our times, urgent and stronger reconnections are needed (Corburn, 2004), incorporating dynamic lines of contemporary research such as urban design and active living. Open public spaces should be planned with ample consideration of the socioeconomic and cultural characteristics of populations, in order to encourage massive adoption of healthy habits such as regular physical activity.

Declarations of interest

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