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Relationship between green space near schools with physical activity and body mass index in portuguese adolescents

Relação entre o espaço verde próximo a escola com a atividade física e índice de massa corporal em adolescentes portugueses

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ABSTRACT

Our aim was to determine the relationship between urban green spaces (UGS) number and greenness amount close to school with physical activity (PA) and body mass index (BMI) of adolescents. Participants (n = 194, aged 13–18 years) were recruited in 75 public secondary schools in the Porto Metropolitan Area. We used a self-administered questionnaire to obtain information on height, weight, age and sex. PA levels were assessed using accelerometers. UGS number and greenness amount were measured using network buffers by 300, 500, 1000 and 1500 meters around each school, through geographic information system and normalized difference vegetation index (NDVI), respectively. Multilevel regressions were fitted to each green indicator individually. Multilevel models without adjustment showed a direct relationship between PA and NDVI [B = 118.14; 95%CI: 20.71, 215.57] and inverse relationship between PA and UGS number [B = -5.95; 95%CI: -10.06, -1.83] at 300 meters. Multilevel models with adjustment for socioeconomic deprivation showed a direct relationship between BMI and NDVI [B = 83.41; 95%CI: 30.84, 135.98] at 500 meters and a direct relationship between BMI and NDVI [B = 61.68; 95%CI: 3.07, 120.29] at 1000 meters. The present investigation does not support the idea that UGS number and the NDVI close to school promote PA and metabolic health in adolescents, as the results proved to be inconsistent and dependent on the distance threshold used to define geographic proximity.

Keywords: Health; Obesity; Parks; Vegetation.

RESUMO

O objetivo foi determinar a relação entre quantidade de espaços verdes (EV) e quantidade de vegetação na proximidade da escola com a atividade física (AF) e índice de massa corporal (IMC) em adolescentes. Os participantes (n = 194, com idades de 13 a 18 anos) foram recrutados em 75 escolas públicas secundárias da Área Metropolitana do Porto. Altura, peso, idade e sexo foram reportadas por questionário e a AF avaliada por acelerómetros. A quantidade de EV e de vegetação foram medidas em buffers de 300, 500, 1000 e 1500 metros ao redor da escola, através de Sistema de Informação Geográfica e índice de vegetação por diferença normalizada (IVDN), respetivamente. Regressões multinível foram realizadas individualmente com cada indicador de verde. A regressões sem ajuste demonstraram relação direta entre a AF e IVDN [B = 118,14; IC95%: 20,71; 215,57] e relação inversa entre a AF e quantidade de EV [B = -5,95; IC95%: -10,06; -1,83] a 300 metros. Modelos ajustados para a privação socioeconómica, apontaram relação direta entre a AF e IVDN [B = 130,18; IC95%: 7,30; 253,07], relação inversa entre a AF e quantidade de EV [B = -5,67; IC95%: -9,87; -1,47] a 300 metros, relação direta entre o IMC e IVDN a 500 [B = 61,68 ;IC95%: 3,07; 120,29] e a 1000 metros [B = 67,68; IC95%: 3,07; 120,29]. A presente investigação não suporta a ideia de que os EV e o IVDN próximos da escola promovem a AF e a saúde metabólica dos adolescentes, pois os resultados foram inconsistentes e dependentes do limiar de distância usado para definir proximidade geográfica.

Palavras-chave*: Saúde; Obesidade; Parques; Vegetação.*

Introduction

The engagement in physical activity (PA) especially during adolescence is associated with healthy weight, cardiometabolic health, mental health, bone strength and physical fitness[2]. Although these benefits are well established in the literature, a substantial proportion of young people does not meet PA guidelines[3].

Studies indicate that the time devoted to PA tends to decrease during the transition from childhood to adolescence[4], with PA being increasingly replaced by sedentary activities[4].

Since low levels of PA are consistently related to the weight of young people, increasing levels of PA have been recommended as part of youth obesity prevention strategies[5].

In addition to insufficient PA levels, the global epidemic of pediatric obesity has been largely related to determinants of the built environment[6]. Studies show that urban environments seem to help promote inactive lifestyles and excessive consumption of high-fat foods, thus contributing to weight changes that are harmful to health[6] .

In this context, ecological models have received special attention from researchers, since they comprise a wider range of potential approaches related to obesity[6]. Identifying the determining factors of the physical environment that are associated with PA, overweight and obesity, especially in young populations, can assist in the development of effective strategies regarding the prevention and / or treatment of this chronic non-communicable disease[2].

Since most adolescents attend school outside the home, spending almost half of their days (or more) in there, several studies consider school as the second main context of everyday life and many international policies identify the area around the school as part of an essential context in promoting healthy behaviors for these populations[3].

Among the environmental determinants observed near the school areas that influence young people's health behaviors, the presence of green spaces has received increasing attention from researchers[7].

Exposure to green spaces in urban areas seems to be able to reduce the risk of several adverse health outcomes through different paths, with PA being identified as one of the main ways[8].

In this context, since urban green spaces (UGS) offer the possibility for individuals to be physically active, these areas appear to be increasingly relevant environmental attributes for the management of excess adiposity, since they seem to help to mitigate excess fat. weight and obesity[8] .

Despite several studies reporting an association between UGS, PA and adiposity, most researchers have looked primarily at adults and children, and the mechanisms underlying the health benefits of green spaces have yet to be fully established[3].

Different definitions of green areas were used in these aforementioned studies, with most using the distance to the UGS. In view of this, the EEA (European Environment Agency) recommends that the urban population should have an UGS at their disposal at a distance of 15 minutes on foot, which corresponds to about 900 – 1000 meters[7].

The method commonly used to assess availability to the UGS involves quantifying these spaces, within a circular buffer around the location to be investigated[8], where the radius of the buffers used to identify the spaces Surrounding greens varies across existing studies, from 30 to 3,000 meters[9]. Availability to the UGS within a buffer can be assessed both using national land use databases[9] and the distance (Euclidean or network) from the study site to the green space entrance closest[9].

In addition to availability, research suggests that exposure to UGS is also capable of positively influencing human health, as a result of the biological diversity of these environments, which are able to accommodate both varieties of species (animals, plants and microorganisms) and varieties of ecosystems. There is evidence that many observed associations between exposure to green environments and human health are mediated by different ecosystem services. In this scenario, exposure to urban green is often measured using the Normalized Difference Vegetation Index (NDVI). The NDVI is a generic indicator that measures the greenness, density and health of vegetation in each pixel of an image. While this index is useful and can be computed using free satellite imagery, to fully measure exposure to green space in a certain location, it is advisable to combine it with measures of availability/accessibility to urban green spaces. UGS (defined in this research as urban parks, gardens and nearby green spaces, managed by the Municipal Councils of Porto Metropolitan Area or privately owned but with free access to the public.) instead of general vegetation, may be more attractive and thereby beneficial as they tend to be safer and better equipped (e.g. with sports equipment, playgrounds, and other amenities), which may promote their usage among children and adolescents.

Under this background, the present study aimed to investigate the association between the UGS number and the greenness amount in the environment around school with PA and Body Mass Index (BMI) of Portuguese adolescents.

Methods

The Porto Metropolitan Area (PMA) (see Figure 1 A) is a metropolitan area in northern Portugal centered on the City of Porto, Portugal's second largest city.

The PMA is made up of 17 adjoining municipalities (see figure 1 B), distributed in an approximate area of 2040 square kilometers[10] with a population of about 1,700,000 inhabitants[11].

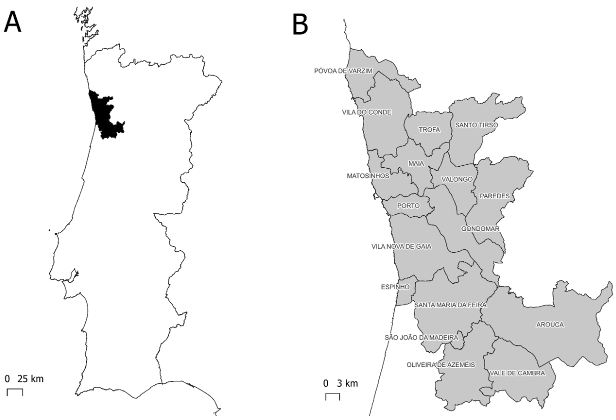

Figure 1 – Location of the Study area: A. Geograpich location of the Porto Metropolitan Area (PMA); B. Municipalities belonging to the Porto Metropolitan Area (PMA).

Data for this cross-sectional survey, were collected between February 2014 and May 2019 from 9 of the 75 public secondary schools in 4 municipalities (Maia, Porto, Matosinhos e Valongo) of the PMA. The schools were selected by convenience, according to the consent of school administrators and physical education teachers, after a briefly presentation of the study objectives. Only adolescents enrolled in physical education classes whose teachers agreed to participate in the research were invited to collaborate.

The total sample consisted of 311 participants residing in PMA; however, due to lack of data, some participants could not integrate the final sample, which was made up of 194 adolescents (111 girls, 83 boys) between 13 and 18 years old.

Prior to data collection, both participants and their parents/legal tutors received a complete explanation of the purpose and procedures of the investigation and signed a written consent form to participate in the study.

According to principles presented in declaration of Helsinki, Ethical approval for this study was obtained from the Ethic Committee of the Faculty of Sports of the University of Porto (CEFADE 22.2013). Educational Authority and School Board consents were also obtained.

Information on height, weight, age, gender was obtained through a self-administered questionnaire.

In general, the measure commonly used to define the weight status is the BMI and associations between BMI and health outcomes within and between populations are often used to help determine possible causes of illness[12].

The BMI was calculated as weight in kilograms divided by height in meters squared (kg/m2) and BMI z-score was categorized into normal weight [1 standard deviation (SD)] and overweight and obesity [>+1SD][12]. For analysis purposes, the overweight and obesity categories were grouped into just one category. This grouping approach is accepted as a useful strategy in exploratory analyses and as a reasonable way to enhance detection of general trends that otherwise might be unnoticeable with the inclusion of a full range of data[6].

Actigraph accelerometers, model GT3X + (Actigraph, Pensacola, FL) were used to assess the participants' physical activity (PA) levels. The volunteers used the device attached to an elastic band, positioned on the right side of the pelvic girdle, during all waking hours for seven consecutive days, removing only during water activities, including bathing.

For data analysis, only participants with a minimum of 600 minutes of daily use during 4 days of the week and 1 day of the weekend or with a total sum of 3,000 minutes or more of use in 4 days[13].

The epoch was set at 30 seconds and Evenson's cutoff points[14] were used to categorize PA with moderate to vigorous intensity.

We considered a total of 226 public green spaces without restrictions on size, location or characteristics, to cover the universe of public green spaces available in the study area that could be freely (at no cost) used by the population. The UGS included public green spaces, such as urban parks, gardens and proximity green spaces, which are administered by the city councils of PMA or privately owned but freely accessible to the public. Green space polygons and entrance locations were obtained from the city council's digital maps, described in previous studies[15].

Using the point location of each child's school as a origin and using network-based measures of distance to green spaces, we counted how many green spaces adolescents had within 300, 500, 1000 and 1500 meters from the school (count). When green spaces were bounded (i.e. with fencing) we used the distance to the entrance; otherwise, the distance to the boundary was used.

For these analyses, we used ArcGIS version 10.5 software and the Network Analyst extension, using an updated street network dataset provided by the Environmental Systems Research Institute.

To capture the vegetation surrounding the school, we calculated the average Normalized Difference Vegetation Index (NDVI) using network buffers of 300, 500, 1000 and 1500 meters around the school. NDVI is calculated based on the reflectance of the soil surface, the visible red (R) and near infrared (NIR) wavelengths, using the formula presented in equation 1.

$$NDVI = (NIR-R) / (NIR + R) \quad (1)$$

The underlying principle employed in calculating NDVI is that chlorophyll in healthy vegetation absorbs radiation in the visible red region (630-690 nm) of the electromagnetic spectrum and reflects radiation in the near infrared region (760-900 nm). It is an index without unit that varies from -1 to 1, where the highest values correspond to a higher density of healthy vegetation. For this study, images of the spring / summer (peak of vegetation) period 2016-2017 were used, which presented 5% or less of the Landsat 8 cloud cover (spatial resolution: 30 m)[16]. We computed the NDVI of each image that fulfill those requirements and then we computed the average NDVI for the period 2016-2017.

For processing satellite images, the software ArcMap 10.5 was used and, QGIS 3.8.2 was used to extract the average NDVI because it is more efficient at dealing with overlapping buffers.

School environment's socioeconomic deprivation data were obtained from the European Deprivation Index for Portuguese Small-Areas (EDI-PT)[1]. The EDI-PT was produced for the smallest area unit possible (n = 18084 census block groups, mean/area = 584 inhabitants) and resulted from the weighted sum of the eight selected variables: percentage of non-owned households; households without indoor flushing; households without bath or shower; households with five rooms or less (pantries, kitchens, corridors, bathrooms and balconies excluded); individuals with blue-collar (i.e., manual) occupations; individuals with low education level (<= 6th grade); non-employers; unemployed looking for a job; and foreign residents.

EDI-PT is a sensitive measure to capture health inequalities, as it is associated with the population's development and health[1].

In this study, the variable was divided into tertiles (1 for less private and 3 for more private), being classified as "low", "medium" and "high" deprivation, respectively. This strategy aimed to increase the heterogeneity of results[17].

For data analysis, the Statistical Package for the Social Sciences (SPSS) version 25 (IBM Corp, Armonk, NY, USA) was used. The statistical significance level adopted was p <0.05 with 95% confidence intervals.

Descriptive statistics were used to characterize the sample. Independent t test was used to verify the existence of significant differences between the means of the groups (normal weight versus overweight). Multilevel regression models were fitted to each variable individually (single-variable model) to analyze whether the UGS number and greenness amount (NDVI) for distances of 300, 500, 1000 and 1500 meters were associated with PA and BMI. The models were obtained for the entire sample without adjustment, being later adjusted by the EDI-PT of the school area.

The likelihood ratio test was calculated to compare the predictive power of the model and collinearity diagnoses were performed on all variables included in the model.

Since the Intraclass correlation coefficient (ICC) is the ratio of the variance between clusters to the total variance we also calculated for better understanding the proportion of variance between students in different schools neighborhoods[18].

Results

The descriptive characteristics for each variable to the sample and by BMI categories was shown in Table 1. About 57% of the students were girls and about 26% (n = 51) of the sample was overweight/obese The BMI average for the sample was 22.75 ± 3.73 kg/m2, and the BMI of the normal weight group was significantly lower compared to the overweight group. The average time of minutes dedicated to moderate to vigorous physical activity (MVPA) was about 40 minutes, and approximately 85% of the adolescents in our sample did not achieve daily recommendations for 60 minutes of MVPA.

Regarding the EDI-PT, about 44% of the participants studied in areas with high deprivation and 10.8 % studied in low deprivation areas, and the NDVI average at 1000 and 1500 meters from school, was significantly higher for eutrophic group compared to overweight group.

As socioeconomic deprivation seems to play an important role in the association with overweight/obesity, we developed models with adjustment for the socioeconomic deprivation index by the school area (EDI-PT).

Table 1 – Sample characteristics and descriptive statistics for each variable by body mass index - categories. Statistical test performed: Independent t test; *: significant difference (p < 0.05).

	Total sample (n = 194)	Normal Weight (n = 143)	Overweight / obesity (n = 51)	p (within normal and overweight groups)
Age (years), M±SD	16.61 ± 1.44	16.55 ± 1.39	16.85 ± 1.94	-
Weight (kg), M±SD	63.50 ± 11.52	59.02 ± 8.51	75.86 ± 9.98	0.45
Height (m), M±SD	1.67 ± 0.09	1.67 ± 0.09	1.65 ± 0.09	-
BMI (kg/m²), M±SD	22.75 ± 3.73	20.91 ± 1.90	27.62 ± 2.92	0.04*
MVPA Average Daily (minutes), M±SD	40.13 ± 19.91	39.84 ± 20.13	40.94 ± 19.69	0.25
EDI-PT 1 (n)	21.1 % (n = 41)	15.4 % (n = 22)	37.3 % (n = 19)	-
EDI-PT 2 (n)	55.7 % (n = 108)	58.7 % (n = 84)	47.1 % (n = 24)	-
EDI-PT 3 (n)	23.2 % (n = 45)	25.9 % (n = 37)	15.7 % (n = 8)	-
UGS Counts [300m], M±SD	0.93 ± 0.66	0.861 ± 0.64	1.11 ± 0.71	0.35
UGS Counts [500m], M±SD	1.63 ± 0.67	1.61 ± 0.67	1.70 ± 0.67	0.66
UGS Counts [1000m], M±SD	5.27 ± 2.24	6.22 ± 2.33	6.39 ± 1.98	0.24
UGS Counts [1500m], M±SD	10.14 ± 3.04	9.83 ± 2.93	11.03 ± 3.16	0.76
NDVI [300m], M±SD	0.17 ± 0.02	0.18 ± 0.02	0.17 ± 0.02	0.32
NDVI [500m], M±SD	0.17 ± 0.01	0.17 ± 0.01	0.16 ± 0.01	0.10
NDVI [1000m], M±SD	0.17 ± 0.01	0.17 ± 0.01	0.17 ± 0.01	0.04*
NDVI [1500m], M±SD	0.17 ± 0.02	0.17 ± 0.02	0.17 ± 0.01	0.03*

BMI = Body Mass Index; MVPA = Moderate to Vigorous Physical Activity; EDI-PT = European Deprivation Index for Portuguese small-areas; UGS = Urban Green space; NDVI = Normalized Difference Vegetation Index.

From an empty model (without independent variables), we found ICC values of 0.19 for PA and 0.21 for BMI. The ICC values vary between 0 and 1, where the higher ICC denote lower the variability within clusters and greater the variability between clusters.

The multilevel models for PA and BMI, with the UGS variable, without and with adjustment, are presented in Table 2. The unadjusted models demonstrated that only PA was inversely associated with the UGS number 300 meters from the school [B = -5.95; 95%CI: -10.06, -1.83]. Regarding the models with adjustment for socioeconomic deprivation, PA was inversely associated with the UGS number within 300 meters of the school [B = -5.67; 95%CI: -9.87, -1.47], while the BMI in the model with UGS at 1000 meters, was inversely associated with the EDI-PT [B = -2.04; 95%CI: -3.95, -0.13].

Table 3 presents the results for PA and BMI multilevel models, with and without adjustment related to NDVI. The models results without and with adjustment, demonstrated that PA was directly associated with NDVI at 300 meters from school [B = 118.14; 95%CI: 20.71, 215.57 and B = 130.18; 95%CI: 7.30, 253.07]. The model with NDVI at 500 and 1000 meters with EDI-PT, showed, respectively, a direct relationship with the BMI [B = 83.41, 95%CI: 30.84, 135.98 and B = 61.68; 95%CI: 3.07, 120.29].

Discussion

Analysis without adjustment showed that UGS number at 300 meters were inversely associated with PA, and the same analysis, including adjustment for socioeconomic deprivation, showed the same. The analysis of the UGS at 1000 meters with adjustment, showed that the EDI-PT was inversely associated with the BMI. The NDVI at 300 meters was directly related to PA in without and with adjustment analysis. The NDVI at 500 and 1000 meters was directly related to BMI in the adjustment models, and the EDI-PT was inversely related to the BMI in both analysis (500 and 1000 meters) and in the UGS at 1500m analysis.

Contrary to expectations, many of our results showed that the UGS number and the greenness amount were not positively associated with PA and BMI in adolescents. However, it is important to note that our results were inconsistent and dependent on the criteria to define geographic proximity, as no significant associations were observed when considering some sets of variables and distances. Our data does not support the presence of a dose–response relationship a criterion to support a causal association between an exposure to green and an effect (as established by Sir Bradford Hill). In other words, it would be expected that the beneficial effect of green space on PA or BMI would decrease as the buffer size increases, because it is likely that adolescents use

Table 2 – The results of the multilevel regression models for physical activity and body mass index with urban green space for the sample without adjustment and with adjustment.

			without adjustment						with adjustment					
					95 % confidence Interval for B						95 % confidence Interval for B			
	Model	Variables	B	SE B	Lower bound	Upper bound	t	p	B	SE B	Lower bound	Upper bound	t	p
Physical activity	1	UGS Counts [300m]	-5.95	2.08	-10.06	-1.83	-2.85	0.005*	-5.67	2.13	-9.87	-1.47	-2.66	0.008*
		EDI-PT	-	-	-	-	-	-	1.36	2.13	-2.84	5.57	0.64	0.52
		Intercept	45.56	2.39	40.84	50.28	19.04	<0.001*	42.54	5.28	32.10	52.97	8.04	<0.001*
	2	UGS Counts [500m]	-3.84	2.10	-7.99	0.30	-1.82	0.06	-3.46	2.15	-7.70	0.77	-1.61	0.10
		EDI-PT	-	-	-	-	-	-	1.78	2.16	-2.47	6.05	0.82	0.40
		Intercept	46.31	3.72	38.96	53.66	12.43	<0.001*	42.07	6.33	29.58	54.56	6.64	<0.001*
	3	UGS Counts [1000m]	-0.81	0.70	-2.46	0.834	-1.15	0.28	-0.56	0.77	-2.28	1.14	-0.73	0.48
		EDI-PT	-	-	-	-	-	-	2.02	2.72	-4.47	8.53	0.74	0.48
		Intercept	44.89	4.86	32.09	57.69	9.22	<0.001*	39.29	8.95	18.94	59.65	4.38	0.002*
	4	UGS Counts [1500m]	-6.69	0.57	-2.03	0.63	-1.22	0.25	-0.48	0.79	-2.16	1.19	-0.61	0.55
		EDI-PT	-	-	-	-	-	-	1.40	3.65	-6.51	9.32	0.38	0.70
		Intercept	46.75	6.26	31.47	62.03	7.46	<0.001*	41.76	14.30	11.51	72.02	2.91	0.010*
Body mass index	1	UGS Counts [300m]	0.78	0.97	-1.61	3.17	0.80	0.45	0.56	0.78	-1.40	2.53	0.71	0.50
		EDI-PT	-	-	-	-	-	-	-1.50	0.80	-3.59	0.59	-1.86	0.12
		Intercept	21.86	1.29	18.58	25.14	16.86	0.00*	24.97	1.97	20.05	29.90	12.67	<0.001*
	2	UGS Counts [500m]	0.70	1.06	-1.96	3.37	0.66	0.53	0.18	0.88	-2.09	2.46	0.20	0.84
		EDI-PT	-	-	-	-	-	-	-1.57	0.88	-3.85	0.70	-1.77	0.13
		Intercept	21.46	2.03	16.35	26.58	10.55	0.00*	25.38	2.69	18.56	32.21	9.41	<0.001*
	3	UGS Counts [1000m]	-0.20	0.28	-0.86	0.45	-0.73	0.48	-0.32	0.20	-0.80	0.16	-1.53	0.16
		EDI-PT	-	-	-	-	-	-	-2.04	0.79	-3.95	-0.13	-2.58	0.04*
		Intercept	24.18	2.14	18.99	29.37	11.27	0.00*	28.88	2.45	23.18	34.57	11.74	<0.001*
	4	UGS Counts [1500m]	0.15	0.20	-0.33	0.64	0.75	0.47	-0.02	0.20	-0.48	0.43	-0.11	0.91
		EDI-PT	-	-	-	-	-	-	-1.69	1.01	-4.03	0.64	-1.67	0.13
		Intercept	21.04	2.35	15.36	26.72	8.93	0.00*	26.19	3.71	18.08	34.30	7.05	<0.001*

Statistical test performed: Multilevel regression; *: significant difference ($p < 0.05$). UGS = Urban Green space; NDVI = Normalized Difference Vegetation Index; EDI-PT = European Deprivation Index for Portuguese small-areas.

the green spaces located closest to the school. However, if eventually the analysis involved a greater number of schools and their respective surrounding areas, perhaps the results could demonstrate a possibly more reliable relationship. In this context, our unexpected results could derived from some type of unknown selection bias or confounding factor[19].

Nevertheless, considering the limited number of studies on this topic, our findings raise some intriguing discussion points.

Most research on green spaces and health behaviors uses measures of green spaces located in residential vicinity[7] and there are limitations in assuming that exposure is directly related to place of residence, because most adolescents do not spend most of the day at home[20].

Portuguese high school students stay at school, in general, 9 h/day and, according to 2015 data on the countries belonging to the Organization for Economic Co-operation and Development (OECD), Portuguese adolescents spend more time at school than the OECD average[21].

Research on the relationship between UGS and greenness around the school with PA and adolescent weight status, found protective effects[22,23] while others reported negative associations[20, 24]. In view of this, it appears that the current literature on the subject, in addition to being scarce, has documented conflicting results[8].

It also seems important to consider that PA assess-

Table 3 – The results of the multilevel regression models for physical activity and body mass index with normalized difference vegetation index for the sample without adjustment and with adjustment.

			without adjustment						with adjustment					
	Model	Variables			95 % confidence Interval for B						95 % confidence Interval for B			
			B	SE B	Lower bound	Upper bound	t	p	B	SE B	Lower bound	Upper bound	t	p
Physical activity	1	NDVI [300m]	118.14	49.40	20.71	215.57	2.39	0.01*	130.18	62.30	7.30	253.07	2.09	0.03*
		EDI-PT	-	-	-	-	-	-	-0.84	2.65	-6.06	4.38	-0.31	0.75
		Intercept	18.87	8.94	1.23	36.51	2.11	0.03*	18.41	9.05	0.55	36.28	2.03	0.04*
	2	NDVI [500m]	43.54	101.91	-206.24	293.33	0.42	0.68	-107.12	142.85	-402.50	188.24	-0.75	0.46
		EDI-PT	-	-	-	-	-	-	5.03	3.80	-2.90	12.97	1.32	0.20
		Intercept	31.97	17.44	-10.07	74.01	1.83	0.11	48.02	19.26	7.47	88.57	2.49	0.02*
	3	NDVI [1000m]	20.36	101.35	-245.93	286.66	0.20	0.84	-92.40	119.22	-356.72	171.91	-0.77	0.45
		EDI-PT	-	-	-	-	-	-	4.51	3.25	-2.51	11.54	1.38	0.18
		Intercept	35.89	17.43	-9.19	80.97	2.05	0.09	46.57	16.97	7.67	85.48	2.74	0.02*
	4	NDVI [1500m]	25.88	79.16	-160.21	211.98	0.32	0.75	-14.69	81.90	-190.18	160.78	-0.17	0.86
		EDI-PT	-	-	-	-	-	-	3.12	2.81	-3.17	9.42	1.11	0.29
		Intercept	34.84	13.95	2.53	67.16	2.49	0.03*	35.96	13.13	6.70	65.22	2.73	0.02*
Body mass index	1	NDVI [300m]	-15.47	21.94	-67.85	36.90	-0.70	0.50	0.47	21.26	-47.37	48.32	0.02	0.98
		EDI-PT	-	-	-	-	-	-	-1.64	0.97	-3.94	0.65	-1.68	0.13
		Intercept	25.35	3.7	16.35	34.36	6.70	<0.001*	25.76	3.16	18.19	33.33	8.13	<0.001*
	2	NDVI [500m]	-1.38	37.78	-88.93	86.16	-0.03	0.97	83.41	24.95	30.84	135.98	3.342	0.00*
		EDI-PT	-	-	-	-	-	-	-3.16	0.66	-4.58	-1.75	-4.76	<0.001*
		Intercept	22.94	6.40	8.07	37.81	3.58	0.00*	14.76	3.35	7.50	22.01	4.39	<0.001*
	3	NDVI [1000m]	8.74	39.52	-84.54	102.03	0.22	0.83	61.68	25.22	3.07	120.29	2.44	0.04*
		EDI-PT	-	-	-	-	-	-	-2.57	0.67	-4.13	-1.01	-3.792	0.05*
		Intercept	21.22	6.75	5.26	37.18	3.14	0.01*	17.24	3.66	8.36	26.13	4.70	0.03*
	4	NDVI [1500m]	21.11	26.20	37.37	79.61	4.17	0.43	36.05	17.52	-3.94	76.06	2.05	0.07
		EDI-PT	-	-	-	-	-	-	-2.01	0.62	-3.58	-0.43	-3.19	0.02*
		Intercept	19.08	4.57	8.85	29.31	4.17	0.00*	20.39	2.90	13.34	27.45	7.01	<0.001*

Statistical test performed: Multilevel regression; *: significant difference (p < 0.05). UGS = Urban Green space; NDVI = Normalized Difference Vegetation Index; EDI-PT = European Deprivation Index for Portuguese small-areas.

ment measures can help explain these discrepancies. Our research, for example, used MVPA measurements determined through accelerometers, while the others evaluated PA through questionnaires or through active transport. In general, most of the indirect measures overestimate the values measured directly, which translates into substantial discrepancies between indirect methods and direct measures of PA assessment in pediatric populations, which may cause some bias in research with health outcomes[25].

Although, some aspects can be generalized, the environmental barriers that hinder the UGS access are specific to local contexts. Different cities (especially in different countries) have their own land use planning patterns (e.g. residential development type or building density), environmental and social issues. Van Sluijs[3] also suggest that the effects of the individual and social determinants may be able to overcome the environmental determinants on PA levels. These factors, in addition to helping to understand the current situation between different locations, also seem help to explain the divergent literature results[20].

As reported by other studies, a characteristic that seems to be associated with the practice of PA and obesity is the socioeconomic gradient, but the underlying mechanisms that mediate this relationship in adolescents along with environmental characteristics are practically unexplored[26].

The different results patterns between the UGS and greenness around the school and relationship with PA and weight status, also depend on the methodology specific factors, such as the quality, attractiveness and safety of UGS, since these attributes are able to promote or to discourage PA. However, in our research, it was not possible to include information about these characteristics and, moreover, the UGS availability around school does not imply the utilization, since adolescents can only use UGS when they are allowed to go outside the limits of the school.

In this context, Luo[27] states that methodological variation is common in most research on UGS and PA, and that research in this area is limited especially by the lack of details in the description of the characteristics of the UGS, causing low theoretical correspondence, and therefore, mixed results.

In addition to these factors, our hypothesis to explain the fact that we have not observed any protective effect of green areas, includes the fact that green spaces may also encourage sedentary behaviors rather than MVPA, which would be more likely to be translated into greater body weight and therefore higher BMI[27].

Although our results support that the UGS and greenness around the school is not able to improve the PA and the weight status of young people, it is known that the greenness can affect from the environmental quality, the noise reduction, more adequate temperature and lower concentration of air pollutants, even the quality of life, through the mental and physiological stress reduction[27], and in this sense it seems fundamental that urban planning and public health policies to promote strategies for better orientation about the provision and promotion of UGS.

Although this study attempted to fill a knowledge gap association between UGS, PA and adiposity, some limitations need to be recognized. First, as this is a cross-sectional survey, it is not possible to make any inference about causal directions. Second, while self-reported anthropometric data are valuable sources of data, self-reported bias can have important consequences for the accuracy of overweight/obesity screening however, this appears to be an alternative when direct measurement of BMI is not available[28]. Third, we do not have measurements on the use of green spaces, and we assume that availability relates to use, however this may not correspond to reality. Fourth, the calculations for determining the sample size with a confidence level of 95% and a margin of error of 5% resulted in a total of 382 subjects[29] however, despite being considered an a priori estimate of the ideal sample size for this research, the absence of data from some participants forced us to conduct the study using a smaller sample[20]. This may have influenced the results, especially for detecting statistically significant associations between the variables[20]. The use of objective measurements both in terms of UGS and urban vegetation, as well as in terms of PA levels, are to being strengths of this study[25].

Nevertheless, the results presented here can be considered an important contribution to the literature on this topic, since they provide an initial look at the subject. Future studies should replicate our approach using stronger epidemiological designs (e.g. prospective cohorts) and should complement measures of availability/proximity of green spaces with information about their quality, safety and suitability, as these factors are very likely to modify the associations between green spaces and health outcomes.

Conflicts of interest

The authors declare no conflict of interest.

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Author's contributions

Conceptualization Melo J, Ribeiro AI, Pizarro AI e Santos MP; methodology, Melo J, Ribeiro AI e Pizarro AI; data collection, Melo J, Pizarro AI; analysis, Melo J, Ribeiro AI., Pizarro AI; writing—original draft preparation, J Melo J, Pizarro AI, Santos MP; writing—review and editing, Melo J, Pizarro AI, Santos MP. All authors have read and agreed to the published version of the manuscript.

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