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Association between the physical activity environment in schools and childhood obesity: a view under the light of complex systems

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Abstract

Objective: to analyse the relationship between physical activity (PA) environment at schools and obesity in children, the light of complex systems. **Methods:** this is a cross sectional study involved 1.200 children (8.1 ± 1.0 years old and 50% boys) from eight public schools from socially vulnerable neighbourhoods of Petrolina, Brazil. Weight and height measurements were assessed to calculate the Body Mass Index (BMI) and classified as normal weight and overweight. To assess the PA environment at the school, a questionnaire about the structural and organizational environment of the school was applied through a face-to-face interview with the school´s manager was conducted. The association between the PA environment at school and obesity was tested using a Machine Learning technique (Network Analysis) performed on the Jasp software. **Results:** positive associations between BMI and Physical Education classes (0.847), physical education teacher (0.349), break duration (0.564) and indoor sports court (0.662) were observed. Negative associations were seen with sex (-0.212) age (- 0.387), extracurricular PA (-0.492) and playground (-0.557). Additionally, the centrality indicators highlighted extracurricular PA (1.789) as the variables with the highest betweenness values, and BMI with the highest closeness (2.239) and strength (1.230) values. **Conclusion:** Extracurricular PA and the presence of playgrounds at school´s environment are associated with a healthier weight status low-income children.

Keywords: School environment; Physical activity; Obesity; Schoolchildren

Introduction

During childhood, obesity is associated with cardiovascular risk factors, such as dyslipidemia, hypertension, diabetes and coronary heart disease (WHO, 2016), with behavioural and emotional disorders (Rankin et al., 2016), low physical activity (PA) and fitness levels (Thivel, Ring-Dimitriou, Weghuber, Frelut, & O'Malley, 2016), and increased sedentary time (WHO, 2016), becoming a severe health problem. Thus, its early prevention is a public health priority (Cecchini & Vuik, 2019). It is emergent to avoid children´s exposure to obesogenic environments (Egger & Swinburn, 1997), which do not favour the choice of healthy habits, such as adequate caloric intake and PA practice (Di Cesare et al., 2019). The school is recognized as an essential environment to promote

children´s healthy behaviours, considering its pre-planned, segmented, and supervised structure (Adom, Kengne, De Villiers, & Puoane, 2019). Previous studies have shown that the school environment, when well oriented, may lead children and adolescents to adopt a healthier lifestyle (Gallotta et al., 2016; Trigueros et al., 2020).

Childhood is a critical phase to adopt healthy behaviours, such as PA (R. A. Jones, Hinkley, Okely, & Salmon, 2013), which may contribute to a healthy weight status. Nonetheless, PA prevalence at six-to-ten-years-old children has decreased substantially, and a large proportion of schoolchildren are not compliant with PA recommendations (Wu & Chang, 2019). Moreover, for children from low-income families, PA opportunities are even worse, due to the lack of PA environments (Cecchini & Vuik, 2019; WHO, 2016). Thus, the school environment may be a potential environment to promote children´s PA, especially when considering its greater flexibility for structural changes, and the possibility of implementing a transversal health promotion program, which may impact on several children simultaneously. Likewise, it has a fundamental role in providing healthy opportunities, especially in low-income contexts, where schools are the only environment where children may engage in PA (Di Cesare et al., 2019).

Aspects of the school environment, such as physical education (PE) classes, are associated with higher PA levels among students (Silva et al., 2018). In this direction, it is believed that children's PA can be determined by different PA opportunities in school environments that are dynamically interrelated to create a healthier pattern for the involvement of children with PA. (Jurado-Castro, Gil-Campos, Gonzalez-Gonzalez, & Llorente-Cantarero, 2020; Mollborn & Lawrence, 2018). However, in Brazilian students, the results of a previous study showed that participation in PE classes was not associated with students´ protection for overweight and obesity (Coledam, Ferraiol, Greca, Teixeira, & Oliveira, 2018). Furthermore, review studies reported that interventions focusing on changing children's behaviour at the school environment have been ineffective in achieving these goals (D. Jones, Innerd, Giles, & Azevedo, 2020; Love, Adams, & van Sluijs, 2019).

Perhaps, these negative results are because, as far as is known, the studies carried out to identify the relationship between the physical activity environment in schools and childhood obesity started from a linear perspective, which disregards the complex and non-linear nature. of these relationships, especially the complex etiology of the obesity.

According to Schmittmann et al. (2013), a network approach appears to be an effective method for recommending acceptable solutions within a complex system, such as the one between obesity and its correlates. This technique enables discovering critical correlations to intervene by offering theoretical and statistical knowledge on the non-linear interrelationships between all parts that are complexly interrelated by their very nature. The Network Analysis examines the variables (nodes) and their connections (edges) while controlling for all other variables given in the network to obtain partial correlation coefficients (Polishchuk, 2021). Thus, this study aimed to analyse the relationship between PA environment at schools and children´s obesity status, the light of complex systems

Methods

Study Design

This cross-sectional study used data from the "Panpes" project, aimed to analyze the effect of a multicomponent intervention on health and behavioural outcomes of obese children. All the Helsinki Declarations' ethical aspects were followed, and the project was approved by the Research Ethics Committee of Health Science Center (protocol n. 1.311.598) and by the Education Board of the city. Parents and children signed a consent before participating.

Eligibility criteria and Setting

Eligibility criteria for schools and children´s selection was established as follows: public elementary schools should have central and suburban and underserved areas in Petrolina-PE, Brazil. Still, having a covered gym with at least 100 students. Therefore, eight schools met the eligibility criteria. The schoolchildren were considered eligible if they were aged 6 to 10 years, enrolled in one of the eligible schools. Based on this, 2.231 children were eligible. All parents of registered children aged 6 to 10 years were invited, and 1.283 accepted to participate. However, 83 children were not included in the study because they missed school on data assessments. So, 1.200 children, from four different city areas of the city (North, South, East, and West) were analysed.

Measurements were performed during two months (October to December 2015) by five physical education teachers, who were previously trained and supervised by the

project´s coordinator. On the first assessments the first day, an interview was held with the school managers to assess the school's environment and children's sociodemographic data (date of birth and sex). In the following days, the children's anthropometric assessments were carried out. Approximately four days were required to assess all children participating in each school.

Variables and protocols

Anthropometric measurements

Anthropometric measurements were performed (weight and height) according to WHO procedures (WHO, 1995), and carried by previously trained evaluators. Weight was determined on a digital platform scale, Wiso®, model W801, with an accuracy of up to 100 g, and height was determined using a Sanny® metallic measuring tape attached to the wall, with an accuracy of 0.1 cm. Body mass index (BMI) was calculated by dividing body weight with the squared height in meters (kg/m2) and, for analysis purposes, BMI was dichotomized into 0) healthy weight (> 85th percentile) and 1) unhealthy weight (<85th percentile) (WHO, 1995).

PA environment at schools

To assess the PA environment at schools, the questionnaire developed by Melo et al., (Mélo et al., 2013) which aims to analyse preschools' environment for PA was used, and adapted for elementary school. For the present study, the original questions were divided into organizational and structural environment. For the organizational environment, the following issues were considered: 1) Does the school offer PE classes (1st to 4th year)? (0 – Yes x 1 – No); 2) Are the classes taught by a PE teacher? (0 – Yes x 1 – No); 3) How long does each break last; 6) Does the school offer extracurricular PA? (0 – Yes x 1 – No). For the structural ones, the following questions: 1) does the school have an indoor sports court?; 2) does the school have a playground? The answers were dichotomized as 0 = No and 1 = Yes, for analysis.

Data analysis

For descriptive analysis, frequency distribution and chi-square test were used. For analysis of associations, a Machine Learning technique called Network Analysis was used to establish interactions between variables from a graphical representation. The “Fruchterman- Reingold” algorithm was applied so, data were presented in the relative

space in which variables with stronger associations remain together, and the less strongly associated variables were repelled from each other (Fruchterman & Reingold, 1991). The least absolute contraction and selection operator was used to obtain regularization and to obtain a less sparse model (Friedman, Hastie, & Tibshirani, 2008). The partial correlation parameter was adjusted to 0.25 to create a network with greater parsimony and specificity (Foygel & Drton, 2010).

To quantify the importance of each node in the network, we then calculated the betweenness and strength centrality indices: (1) betweenness centrality, estimated from the number of times that a node is part of the shortest path among all other pairs of nodes connected to the network; (2) closeness centrality, determined from the inverse of the distances from one node to all others; (3) strength centrality which is the sum of all the weights of the paths that connect a node to the others.

The variables were configured in three attributes: 1) demographics characteristics; 2) Organizational environment school 3) Structural environment school; 4) Obesity indicators. The positives correlations were represented in blue colour and the negatives correlations in red colour. Analyses were performed in Jasp (0.12.1).

Results

Table 1 shows the results of the prevalence of obesity between sex and age of students. There no significant differences between sexes among age strata.

Table 1. Prevalence of obesity indicators.

Variables	**6-year-old**			**7-year-old**			**8-year-old**			**9-year-old**			**10-year-old**		
	Boys (n=9)	**Girls (n=20)**	**p**	**Boys (n=195)**	**Girls (n=187)**	**p**	**Boys (n=243)**	**Girls (n=214)**	**p**	**Boys (n=191)**	**Girls (n=192)**	**p**	**Boys (n=699)**	**Girls (n=672)**	**p**
BMI															
Healthy (%)	21.6	73.9	.260	51.6	48.4	.647	54.4	45.6	.294	50.2	49.8	.833	51.4	48.6	.561
Unhealthy (%)	50.0	50.0		48.4	51.6		48.5	51.5		48.9	51.1		49.3	50.7	

Chi-Square Test. BMI = Body Mass Index.

The main results of the network analysis showed positive associations between BMI with PE classes (0.847), PE teacher (0.349), break duration (0.564) and indoor sports court (0.662). Negative associations were seen between BMI and sex (-0.212), age (-0.387), extracurricular PA (-0.492) and playground (-0.557).

Table 2. Strength of associations between variables in the perspective of a network stratified by sex.

Variables	1	2	3	4	5	6	7	8	9
1	0.000								
2	-0.212	0.000							
3	-0.387	-0.976	0.000						
4	0.847	-0.270	-0.062	0.000					
5	0.349	0.700	0.641	0.180	0.000				
6	0.564	-0.315	-0.270	-0.499	-0.388	0.000			
7	-0.492	-0.856	-0.942	0.171	0.386	-0.348	0.000		
8	0.662	-0.386	-0.297	-0.671	-0.243	-0.976	-0.301	0.000	
9	-0.557	0.052	-0.151	0.767	-0.473	-0.173	-0.470	0.039	0.000

1 = BMI; 2 = Sex; 3 = Age; 4 = Physical education classes; 5 = Physical education teacher; 6 = Break duration; 7 = Extracurricular physical activities; 8 = Sports court indoor; 9 = Playground

The network between the assessed variables is shown in Figure 1. The blue lines represent the positive associations and the red the negative ones. The thickness of the lines represents the strength of the associations.

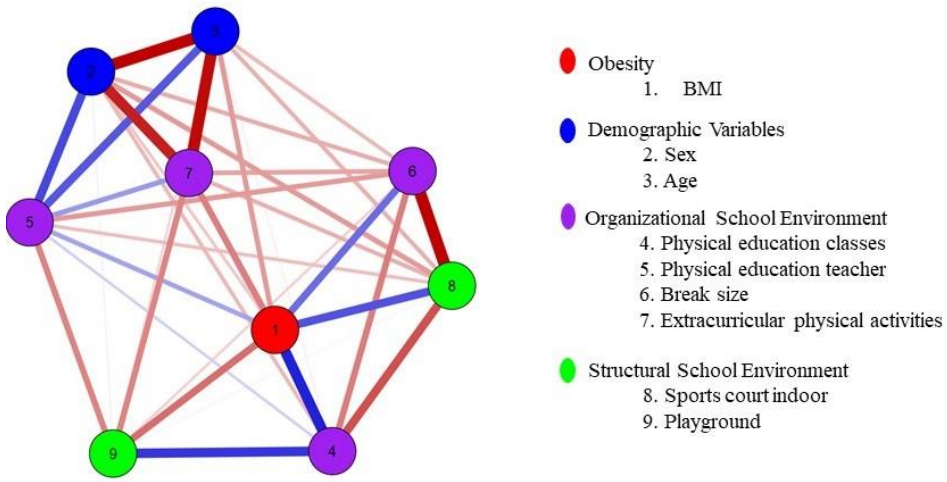

Figure 1. Network analysis.

The centrality indicators highlighted that extracurricular PA (1.789) showed the highest betweenness values, meaning this is the variable with the higher number of network relationships. Furthermore, BMI showed the highest closeness (2.239) and strength (1.230) values, indicating that BMI may be easily impacted by possible changes in the network (Table 3).

Table 3. Centrality measures per variable.

	Network		
Variable	**Betweenness**	**Closeness**	**Strength**
BMI	0.894	2.239	1.230
Sex	-0.894	-0.132	0.481
Age	-0.894	-0.891	0.379
PE classes	0.894	-0.585	-0.260
PE teacher	-0.894	-0.560	-0.524
Break duration	0.000	-0.579	-0.096
Extracurricular PA	1.789	1.024	0.976
Sports court indoor	-0.894	-0.271	0.008
Playground	0.000	-0.244	-2.193

PE: Physical Education; PA: Physical Activity

Discussion

The present study considered the network perspective to investigate the association between the PA environment at schools and children´s obesity status. The main results showed extracurricular PA and BMI as the main network's variables. Previous studies analysed the association between school environment and children's BMI (Coledam et al., 2018; Silva et al., 2018). However, as far as the authors know, this is the first study to consider the school environment's organizational and structural characteristics and BMI as part of a network system. Additionally, this study covered an important gap in the literature, when highlighting this issue for children living in a low-income context.

High obesity levels may promote changes in important health outcomes of school-age children such as shorter sleep duration (Li, Zhang, Huang, & Chen, 2017), lower values of inhibitory control (Mamrot & Hanć, 2019), high cardiovascular risk(Sommer & Twig, 2018), low PA (Elmesmari, Martin, Reilly, & Paton, 2018), and physical fitness levels (Thivel et al., 2016). This fact reinforces the importance of school´s environment in promoting a healthy lifestyle (Adom et al., 2019). Indeed, PA should be encouraged in different settings to promote a healthy lifestyle (Wickel & Belton, 2016), but particularly at school (Heath et al., 2012), and especially among low-income children. It requires remodeling the structural and organizational settings, that could be through PE classes, and trained staff to teach a healthy lifestyle through PA (Trigueros et al., 2019). Although, participation in PE classes has been associated with a better body composition profile (Ten Hoor et al., 2018), and with high levels of cardiorespiratory fitness and muscle strength in Brazilian students (Coledam et al., 2018), a higher intensity and duration of PE classes should be encouraged (Trigueros et al., 2019), especially when considering the heterogeneity in PE offer and classes' procedures among the different Brazilian regions. Furthermore, a school´s curriculum, focused on active breaks, has been reported as effective to increase children´s PA (Groffik, Sigmund, Frömel, Chmelík, & Nováková Lokvencová, 2012).

In the present study, the break duration was positively associated with children´s weight status. This result could be, at least partially, explained by the low break duration in the assessed schools (20 minutes), and the cultural Brazilian context, where children tend to spend their break times chatting on smartphones or snacking. Indeed, overweight children tend to spend less time on moderate to vigorous PA during the break, than their healthy-weight peers (Kobel, Kettner, Erkelenz, Kesztyüs, & Steinacker, 2015). and adequate spaces at schools are key for children to be active during this time (Henrique, Gomes, Tani, & Maia, 2018). Among low-income children, PA environments, such as a sports court, are associated with lower overweight (Hood, Colabianchi, Terry-McElrath, O'Malley, & Johnston, 2014), as schools may offer their unique opportunity to be active (Powell, Slater, Chaloupka, & Harper, 2006).

The negative association between BMI and PA during school hours extra has its partial explanation that all the schools evaluated were in neighbourhoods with high crime, which makes access to school difficult. Over time, especially for children whose parents work and cannot accompany their children in these activities (Goon, Kontulainen, &

Muhajarine, 2020). Another possible explanation is that children with a healthy weight tend to engage more in extra physical activities than overweight (Raistenskis, Sidlauskiene, Strukcinskiene, Uğur Baysal, & Buckus, 2016). Although positive associations have been seen between BMI and PE classes, PE teachers, break duration and indoor sports court, it is also important to highlight that the assessed children live and study in low-income settings, where the quality of those factors must be explored in future investigation. Moreover, extracurricular PA, focusing on structured and supervised activities, and playground to give children opportunity for unstructured PA, should be encouraged towards a health BMI.

Indeed, the approach adopted in this study, which focus on PA as part of a complex system (Brug, 2006), composed of different levels, and that emerges through interactions of different components, including school´s environment, allows to recognize the characteristics of the interrelationships between PA school´s environment and BMI through non-linear, dynamic relationships. Thus, the associations observed are part of a systemic approach, which concept has been introduced to understand the diversity of factors related to health behaviours (Carey et al., 2015), and should not be considered in isolation. Studies using this approach have focused on aspects of public health policies (Mabry, Marcus, Clark, Leischow, & Méndez, 2010), health education (Cooper, Geyer, & Medicine, 2008), and obesity (Christakis & Fowler, 2007). Thus, children PA, as a marker health behaviour, is part of that holistic perspective, that occurs by forming patterns responsive to the entire environmental context (Luke & Stamatakis, 2012).

The present study has some limitations that need to be considered when interpreting its results: a) the questionnaire used to assess the school environment has not been validated and therefore does not present psychometric indicators. However, the questionnaire is quite simple and objective, with closed possible answers, what may reduce the bias risk; b) the lack of children´s PA data is another limitation that should be considered for future studies. Nonetheless, the results cover a representative sample of children living in low-income contexts in Petrolina and used a systemic approach to lead with complex health problem of schoolchildren.

Conclusion

Extracurricular PA and the presence of playgrounds at school´s environment are associated with a healthier weight status in obese low-income children. These results may

support decision making and public policies for school´s settings, towards children´s health lifestyle.

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