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Physical activity is inversely associated with high blood pressure independently of overweight in Brazilian adolescents

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The purpose of this study was to assess the relationship between blood pressure (BP) levels and physical activity (PA) domains accounting for overweight/obesity. Adolescents aged 10 to 17 years old were recruited ($n = 1021$). International Obesity Task Force (IOTF) criteria were used to define overweight and obesity. High BP was defined using the Center of Disease Control and Prevention criteria. Different domains of PA (school activities, sport out of school, and leisure time PA) were assessed using a validated questionnaire. The prevalence of overweight/obesity was 21.9% for boys and 14.8% for girls. Some 13.4% of boys and 10.2% of girls, respectively, had high blood pressure (HBP). A strong and positive association was found between overweight and HBP. After adjustment for body mass index (BMI), total PA was inversely associated with BP. When all PA domains were entered simultaneously in a regression model, and after adjustment for BMI, only sport out of school was significantly and inversely associated with systolic BP [β: –0.82 (–1.50; –0.13)]. These findings open avenue for the early prevention of HBP by the prevention of obesity and promotion of PA.

Hypertension in adults is a major public health problem (Chobanian et al., 2003). Blood pressure (BP) tracks from childhood to adulthood (Chen & Wang, 2008), and high BP (HBP) during childhood leads to the development of adulthood hypertension (Lauer et al., 1989). Several behavioral and environmental factors are related to the development of HBP among children, for example, genetic, intrauterine, socioeconomic, environmental, and lifestyle factors (Guasti et al., 1999; Hemachandra et al., 2007). A better understanding of the factors that affect BP during childhood could help inform the prevention of hypertension (Sinaiko, 2007).

Physical activity (PA) is inversely associated with BP in adults, thus, regular PA is recommended in order to prevent hypertension (Whelton et al., 2002). The association between PA and BP is less well described in children: while some studies suggest a significant inverse relationship between PA and BP (Leary et al., 2008; Resaland et al., 2010; Ullrich-French et al., 2010), other studies do not support such a relationship (Singh et al., 2006).

On one hand, obesity in children and adolescents is a strong correlate of BP (Chiolero et al., 2007a). While childhood obesity has increased rapidly in Brazil (Gomes & Alves, 2009) and could impact mean BP level (Chiolero et al., 2007b), prevalence of HBP has been rarely assessed in this country in children and adolescents. On the other hand, the relationship between obesity and PA levels is controversial. While some studies observed that obesity is related to lower levels of PA among children and adolescents (Epstein et al., 1996; Janssen et al., 2004), others did not confirm this association (Van Der Horst et al., 2007). The effect of different PA domains, for example, school activities, sports out of school, and leisure time activities, on BP and overweight remains unclear, especially in pediatric populations (Abu-Omar & Rütten, 2008; Andersen et al., 2009).

Therefore, our objective was to assess, in a large school-based survey of Brazilian adolescents, the relationship between BP levels and different PA domains, accounting for overweight/obesity.

Materials and methods

Design and human volunteers

This cross-sectional study was carried out in Londrina City, Southeast Brazil (Christofaro et al., 2009a). Adolescents aged 10 to 17 years old were randomly selected, using a random two-stage sampling scheme [1st stage: regions (east, west, north, south, and center of the city); 2nd stage: schools (public and private schools in each region)]. According to the Municipal Education Department, the city of Londrina had approximately 70 000 schoolchildren enrolled in the 5th to 8th grades of state and private schools. Sample size was estimated through specific equation (Fisher & Belle, 1993): assuming an expected prevalence of HBP in boys and girls of 10%, 916 participants were required to have a tolerable error of 3% (i.e. 95% confidence interval: 7–13%) with a power of 80%. Out of the 1144 invited to participate, 1021 adolescents (493 boys and 528 girls) participated (participation rate: 89.2%).

Both the adolescents and their parents were informed about methodological procedures. The latter had to sign a written consent form to have their children participate. This study was approved by the Ethics Committee on Human Experimentation of the institution that conducted this study.

Anthropometric measures

Measurements were performed at school by trained health professionals. Body weight and height were measured using a digital scale (Plenna®, Plenna industry, São Paulo, São Paulo, Brazil) and a wood wall-mounted stadiometer, respectively. Adolescents were measured in light clothes and without shoes. In order to avoid possible embarrassment, adolescents had their weight measured in a separate quiet room. Body mass index (BMI) was calculated as weight (kg) / height (m)^2. Sex- and age-specific International Obesity Task Force (IOTF) BMI cutoffs were used to define normal weight, overweight, and obesity (Cole et al., 2000).

BP measures

Systolic and diastolic BP was assessed using the oscillometric devices Omron HEM 742 (Omron Corporation, Kyoto, Kansai, Japan). This device was clinically validated for adolescents (Christofaro et al., 2009b). BP was measured after weight and height measurements. Subjects rested in the sitting position in a separate and quiet room for 5 min with their back supported and feet on the ground following the recommendations of the American Heart Association (Pickering et al., 2005).

Two BP readings were taken at a 2-min interval and averaged. In case of large difference between the two measures, two additional measurements were gathered and the mean of the last two measures were adopted. This procedure was necessary for approximately 5% of the 1021 participants. *Z*-scores and corresponding percentiles of BP were generated using the Center of Disease Control and Prevention reference tables. “High BP” was defined as systolic BP and/or diastolic BP equal to or above the reference sex-, age-, and height-specific 95th percentile, following the National High Blood Pressure Education Program (NHBPEP) criteria (NHBPEP Working Group on High Blood Pressure in Children and Adolescents, 2004). Adolescents with HBP were referred to a physician in a Basic Healthcare Unit (Brazilian Public Health System).

Physical activity domains

PA was assessed using the validated questionnaire developed by Baecke et al. (1982), which produces a physical activity score. In a validation study, this score was significantly related to energy expenditure measured by doubly labeled water method: [$r = 0.69$ ($P = 0.001$)] (Philippaerts et al., 1999). Baecke’s questionnaire evaluates PA through three different domains (school activities, sports out of school, and leisure time activities). The sum of these three domains is defined as the total PA. For each domain, a dimensionless score was obtained.

Statistical procedures

Mean and standard deviation were adopted as descriptive statistics. Correlations between PA scores of each domain were assessed using Spearman correlation. Chi-square test was used to assess associations between categorical variables. Two-way analysis of variance was used to compare continuous variable in normal weight and overweight/obese participants. To assess the relationship between BP and PA, we fitted linear regression models with each PA domain or with total PA as independent variables. A *P* value below 0.05 was considered as statistically significant. Analyses were conducted with SPSS (version 13.0, SPSS Inc., Chicago, Illinois, USA).

Results

Out of 1144 adolescents invited to participate, 123 declined and 1021 subjects participated (participation rate: 89.2%), that is, 493 boys and 528 girls. Most participants were 11 to 13 years old. Some 21.9% (95% CI: 18.3–25.8%) of boys and 14.8% (95% CI: 11.8–18.0%) of girls were overweight [both sexes together: 18.2% (95% CI: 15.8–20.7%)]. Some 13.4% (95% CI: 10.5–16.7%) of boys and 10.2% (95% CI: 7.7–13.1%) of girls had HBP, respectively [both sexes together: 11.8% (95% CI: 9.8–13.8%)].

Mean BP was higher in overweight than normal weight adolescents, in both sexes (Table 1). Boys presented higher scores of PA in all domains, except for school activities. In all PA domains, the scores were not statistically different between overweight/obese and normal weight children.

PA domains were positively related to each other (Table 2). A strong correlation was found between the practice of sports out of school and PA during leisure time, and between PA during school activities and sports out of school. Similar relationship was observed for boys and girls.

A strong linear relationship was observed between BMI and systolic BP [regression coefficient: 0.66 mm Hg/kg/m^2 (95% CI: 0.45; 0.86)] and diastolic BP [regression coefficient: 0.50 mm Hg/kg/m^2 (95% CI: 0.37; 0.64)]. Age was associated with overweight/obesity ($P = 0.001$), but not with HBP ($P = 0.210$).

In different linear multivariable regression models, total PA was negatively associated with systolic and diastolic BP, with or without adjustment for BMI (Tables 3 and 4). School PA and sport out of school were negatively associated with systolic BP – with or without adjustment for BMI (Table 3). Leisure time PA was not statistically significantly associated with systolic BP. While school PA was not associated with diastolic BP, sport out of school and leisure time PA were inversely associated with diastolic BP – with or without adjustment for BMI (Table 4). When all PA domains were entered simultaneously in the regression model, only sport out of school remained significantly associated with systolic BP.

Discussion

In this school-based sample of Brazilian adolescents, overweight, obesity, and HBP were highly prevalent. A

Table 1. Characteristics of participants by sex and presence of overweight/obesity

	Boys ($n = 493$)		Girls ($n = 528$)	
	Normal weight Mean (SD)	Overweight/Obese Mean (SD)	Normal weight Mean (SD)	Overweight/Obese Mean (SD)
Age (years)	12.2 (1.5)	11.6 (1.3)	12.1 (1.4)	11.7 (1.3)*
BMI (kg/m^2)	17.83 (2.1)	24.81 (3.0)	17.95 (2.3)	24.17 (2.55)
Systolic BP (mm Hg)	112.6 (11.6)	115.6 (11.5)	110.7 (11.7)	114.0 (10.6)*
Diastolic BP (mm Hg)	60.8 (7.5)	64.7 (8.6)	62.9 (7.7)	65.2 (7.1)*†
PA domains score				
PA school	2.6 (0.4)	2.6 (0.4)	2.6 (0.4)	2.6 (0.4)
PA sport	3.2 (1.1)	3.3 (1.2)	2.7 (1.0)	2.7 (1.0)†
PA leisure	2.6 (0.7)	2.6 (0.7)	2.4 (0.7)	2.4 (0.7)†
PA total	8.5 (1.7)	8.6 (1.8)	7.8 (1.6)	7.8 (1.7)†

Difference between groups evaluated by two-way analysis of variance.

*$P < 0.05$ for the difference between overweight and normal weight.

†$P < 0.05$ for the difference between boys and girls.

BMI, body mass index; BP, blood pressure; PA, physical activity; PA leisure, score related to activities performed at leisure time; PA school, score related to physical activities performed at school; PA sport, score related to sport activities performed at leisure time; PA total, sum of the physical activity scores related to school, sport, and leisure activities; SD, standard deviation.

Table 2. Spearman correlation among physical activity domains

Variables	Physical activity (PA) domains	
	Sport out of school	Leisure time PA
School PA	$r = 0.20$	$r = 0.09$
P	0.001	0.003
Sport out of school	–	$r = 0.37$
P		0.001

strong association was found between overweight and HBP. Boys were more physically active than girls. Total PA was inversely associated with BP, independently of BMI. While the various domains of PA were related to each other, an inverse association was found between the practice of sport out of school and BP but less so with leisure time PA or PA during school.

The prevalence of HBP in this study was 11.8%. As BP was based on the average of two readings obtained at one unique visit, BP and the prevalence of HBP may be overestimated and some cases may have been misclassified in the HBP group (Pickering et al., 2005). Previous studies that also measured BP at one visit reported prevalence of HBP, ranging from 3.6% to 20.6% (Oliveira et al., 2004; Urrutia-Rojas et al., 2006). In our study, the prevalence of HBP was, for instance, lower compared with the prevalence in young adolescents in the USA (Urrutia-Rojas et al., 2006) and similar compared with the prevalence in Switzerland (Chiolero et al., 2007a). This is possibly consistent with the larger prevalence of overweight in the USA than in Brazil or Switzerland.

The association between obesity and HBP in children and adolescents of North America (Urrutia-Rojas et al., 2006), Europe (Genovesi et al., 2008), Asia (Jafar et al., 2005), Africa (Chiolero et al., 2007b), and South America (Gomes & Alves, 2009) has been well described and was confirmed in this study. The proposed mechanisms underlying the relationship between obesity and BP in childhood are related to numerous factors, for example, adipokines released in bloodstream by excessive adipose tissue that affect cardiovascular system functions (Huang, 2009; Kotsis et al., 2010).

In the present study, the total PA was inversely associated with BP and this finding agrees with previous researches that analyzed pediatric populations (Ekelund et al., 2006; Leary et al., 2008). However, none of the previous studies had analyzed the association between different PA domains and BP. In our study, lower BP was associated mainly with the practice of sport out of school.

Considering that sports PA out of school may be more intense than leisure time PA or PA during school, our results suggest that improvements in BP levels with PA programs among children and adolescents could be achieved toward the increase of sports PA out of school. Moreover, there is a tracking of sport practice from youth to adulthood (Van Mechelen et al., 2000; Fernandes & Zanesco, 2010) and this tracking of sport practice may be higher than in other PA domains (Van Mechelen et al., 2000). Although this impact of increasing sport activity on BP should be tested in future studies, our findings support the recommendations of the American Heart Association (Daniels et al., 2005) that stands the importance of intense PA for the health of children and adolescents.

One major finding of this study is that the inverse association between PA and BP is independent of BMI. Thus, increasing PA levels, with or without changes in obesity status, might be important to improve BP levels in children and adolescents. In the same line of our study, Fernandes and Zanesco (2010), in a large epidemiological study involving Brazilian adults, found a relationship

Table 3. Relationship between systolic blood pressure and different physical activity domains

Systolic blood pressure						
PA domain	Adjusted: age and sex			Adjusted: age, sex, and BMI		
	Beta	*P*	95% CI	Beta	*P*	95% CI
Entered separately in the regression model						
Total	–0.55	0.009	(–0.97; –0.14)	–0.58	0.006	(–0.99; –0.16)
School	–1.59	0.042	(–3.12; –0.06)	–1.74	0.024	(–3.25; –0.22)
Sport	–0.89	0.006	(–1.53; –0.26)	–0.90	0.005	(–1.52; –0.27)
Leisure	–0.27	0.574	(–1.21; 0.67)	–0.33	0.488	(–1.26; 0.60)
Entered simultaneously in the regression model						
School	–1.19	0.134	(–2.76; 0.36)	–1.34	0.087	(–2.89; 0.19)
Sport	–0.84	0.016	(–1.53; –0.15)	–0.82	0.018	(–1.50; –0.13)
Leisure	0.23	0.650	(–0.77; 1.23)	0.16	0.739	(–0.82; 1.15)

BMI, body mass index; PA, physical activity; 95% CI, 95% confidence interval.

Table 4. Relationship between diastolic blood pressure and different physical active domains

Systolic blood pressure						
PA domain	Adjusted: age and sex			Adjusted: age, sex, and BMI		
	Beta	*P*	95% CI	Beta	*P*	95% CI
Entered separately in the regression model						
Total	–0.49	0.001	(–0.78; –0.21)	–0.52	0.001	(–0.79; –0.24)
School	–0.70	0.185	(–1.73; 0.33)	–0.83	0.106	(–1.84; 0.17)
Sport	–0.63	0.004	(–1.06; –0.20)	–0.63	0.003	(–1.05; –0.21)
Leisure	–0.88	0.006	(–1.52; –0.24)	–0.93	0.003	(–1.55; –0.31)
Entered simultaneously in the regression model						
School	–0.37	0.489	(–1.42; 0.68)	–0.50	0.333	(–1.53; 0.52)
Sport	–0.45	0.056	(–0.92; 0.01)	–0.43	0.063	(–0.88; 0.02)
Leisure	–0.63	0.068	(–1.30; 0.04)	–0.68	0.041	(–1.34; –0.02)

BMI, body mass index; PA, physical activity; 95% CI, 95% confidence interval.

between sport practice in youth and BP levels independently of the obesity status in adulthood, suggesting that improvements in physical activity throughout life may help prevent hypertension and whatever its effect is on adiposity.

The mechanisms underlying the hypotensive effects of PA have not been well studied in epidemiologic studies, especially in pediatric populations. Trigona et al. (2010) identified that flow-mediated dilation is increased in physically active children and adolescents. Clinical studies have suggested that the effects of PA on BP are mediated by neurohormonal, vascular, and structural adaptations, such as the higher release of nitric oxide, a reduction in peripheral sympathetic nervous activity, a reduction in the release of catecholamine, and a decrease in arterial stiffness (Zanesco & Antunes, 2007; Mark & Janssen, 2008).

Our study has several strengths. It was performed in a middle-income developing country, for which very limited information is available on the prevalence of HBP and on the factors associated with BP such as PA. The sample was representative of school adolescents of one large city, which has similarities with a large number of Brazilian cities of the same size. BP was measured with an automated device that was clinically validated (Christofaro et al., 2009b). Using automated devices allows us to prevent some observer bias. Finally, several domains of PA were assessed, allowing the identification of specific associations between theses domains and BP.

However, this study has several limitations. First, our findings represent only the urban area and may not be applied to the rural area of Brazil. Second, while this questionnaire was validated against a gold standard for energy expenditure and allowed us to assess various domains of PA (Baecke et al., 1982), it did not allow us to assess the total amount of PA as it would be possible, for example, with an accelerometer (Rowlands, 2007). A large variety of studies analyzing PA and BP in pediatric populations used other tools to assess PA (Ekelund et al., 2006; Leary et al., 2008) and, therefore, comparisons with our findings are limited. Third, sport practice is a PA domain of easier recall than other domains in children and adolescents (Bratteby et al., 1997) and, thus, this point must be taken into account in the analysis of the relationship between PA domains and BP. Finally, the absence of other cofactors associated with overweight and BP (e.g. dietary habits and body fat distribution) and the cross-sectional design of the study should be considered.

Perspectives

This study has important potential public health implications. The high prevalence of HBP and overweight among Brazilian adolescents emphasize the need for programs to prevent hypertension and obesity early in life. The negative association between BP and PA was independent of obesity status. Therefore, increasing PA levels, with or without changes in obesity status, might be important to improve BP levels in children and adolescents.

Key words: physical activity, hypertension, overweight, adolescents.

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