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ORIGINAL ARTICLE

Body adiposity is associated with risk of high blood pressure in Portuguese schoolchildren

Paulo Rogério Melo Rodrigues[a,h,*], **Rosangela Alves Pereira**[b], **Augusta Gama**[c,h], **Isabel Mourão Carvalhal**[d], **Helena Nogueira**[e,h], **Vitor Rosado-Marques**[f,h], **Cristina Padez**[g,h]

[a] *College of Nutrition, Federal University of Mato Grosso, Mato Grosso, Brazil*
[b] *Department of Social and Applied Nutrition, Federal University of Rio de Janeiro, Rio de Janeiro, Brazil*
[c] *Department of Animal Biology, Faculty of Sciences of the University of Lisbon, Portugal*
[d] *Research Center in Sport Science, Health and Human Development, Vila Real, Portugal*
[e] *Department of Geography, University of Coimbra, Portugal*
[f] *Tropical Research Institute, Lisbon, Portugal*
[g] *Department of Life Sciences, University of Coimbra, Portugal*
[h] *Research Center for Anthropology and Health, University of Coimbra, Portugal*

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KEYWORDS
Blood pressure;
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Weight status

Abstract
Objective: The aim of the study was to estimate the prevalence of high blood pressure (HBP) and its association with anthropometric indicators of adiposity in Portuguese schoolchildren.
Methods: In this cross-sectional study, a nationally representative sample of 6-9-year-old children was analyzed. Weight and height (used to calculate body mass index [BMI]), blood pressure (BP), waist circumference (WC) and skinfold thickness (used to estimate body fat percentage [BFP]) were measured using standard techniques. BP was classified as high-normal BP or hypertension for values between the 90th and 95th percentiles or above the 95th percentile, respectively. A body adiposity index was calculated with principal component analysis using BMI, WC and BFP. Multinomial logistic regression models were used to estimate the strength of the association between anthropometric indicators and HBP.
Results: The prevalence of high-normal BP and hypertension was 4.5% and 3.7%, respectively. BP was positively correlated with all anthropometric indicators ($p < 0.01$ for all). HBP was significantly more prevalent in females than in males and was positively associated with higher values of the assessed anthropometric indicators of adiposity, especially among females.
Conclusion: Increased body fat predicted HBP. The use of anthropometric indicators may thus be useful in screening for HBP among Portuguese schoolchildren.

* Corresponding author.
E-mail address: prmr84@gmail.com (P.R.M. Rodrigues).

PALAVRAS CHAVE
Pressão arterial;
Escolares;
Adiposidade;
Condição de peso

Adiposidade corporal está associada com o risco de pressão arterial elevada em escolares portugueses

Resumo
Objetivo: Estimar a prevalência de hipertensão arterial sistêmica (HAS) e sua associação com indicadores antropométricos de adiposidade em escolares portugueses.
Métodos: Neste estudo transversal, uma amostra nacionalmente representativa de crianças de seis a nove anos foi avaliada. As medidas de peso e altura (usadas para estimar o índice de massa corporal [IMC]), pressão arterial [PA], circunferência da cintura [CC] e dobras cutâneas {usadas para estimar o percentual de gordura corporal – PBF}) foram aferidas com procedimentos-padrão. A HAS foi classificada em pressão arterial normal-alta ou hipertensão para valores entre os percentis 90 e 95 ou acima do percentil 95, respectivamente. Um índice de adiposidade foi estimado por meio da análise de componentes principais com o uso de IMC, CC e BFP. Modelos de regressão logística multinomial foram usados para estimar a magnitude da associação entre indicadores de adiposidade e HAS.
Resultados: As prevalências de pressão arterial normal-alta e hipertensão foram de 4,5 e 3,7%, respectivamente. A HAS foi positivamente correlacionada com todos os indicadores de adiposidade (p < 0,01 para todos). HAS foi significativamente maior em meninas do que em meninos e foi positivamente associada com o aumento dos indicadores antropométricos de adiposidade, especialmente entre as meninas.
Conclusão: O aumento da gordura corporal pode predizer HAS. Assim, o uso de indicadores antropométricos para adiposidade pode ser útil na triagem de HAS em escolares portugueses.

Introduction

The growing childhood obesity epidemic[1] is concerning, especially because obese children may experience metabolic complications and are at high risk for the early development of conditions that are more commonly observed in adults,[2] particularly high blood pressure (HBP), changes in serum triglycerides and elevated fasting glucose.[3]

The prevalence of childhood hypertension had been expected to be approximately 1-2%,[4] however, rates ranging from 3.0 to 15.9% have been observed in different scenarios,[5–19] and this rise is associated with increases in excess weight,[2,3,18,19] increased abdominal fat,[7,9–14,17] and unhealthy lifestyles.[9,10,15,20]

Additionally, hypertension in childhood has important implications for children's health, since it is commonly related to the development of other cardiovascular risk factors[3,21] and can persist into adulthood.[22,23] However, although early diagnosis of hypertension in children is of the utmost importance[24] and blood pressure (BP) measurement is a low-cost, noninvasive and relatively accurate procedure for identifying this condition,[25] little is known about the risk factors associated with HBP in childhood.

The aim of this study was to estimate the prevalence of HBP and its association with anthropometric indicators of adiposity in Portuguese schoolchildren.

Methods

Sampling method

The present study used a subsample of the Portuguese Prevalence Study of Obesity in Childhood (PPSOC),[26,27] a cross-sectional study carried out between March 2009 and January 2010 investigating a randomly selected sample from public and private schools in mainland Portugal. The study was designed to obtain a nationally representative sample of 3-10-year-old children living in mainland Portugal. The sampling design was stratified proportionally according to the age and gender of the children in each district. Details of the study design and sampling process can be found elsewhere.[26,27] This study included a subsample of 1555 6-9-year-old children from the 18 districts in Portugal.

Data collection

A questionnaire designed specifically for this research was applied to the children's parents and included questions on demographic and socioeconomic characteristics, lifestyle-related behaviors, and health and nutrition. A pilot test was conducted on a group of children similar to those in the study, and the questionnaire was revised based on the pilot results. To reduce the non-response rate, three visits were made to each school to examine previously absent students. Anthropometric and BP measurements were performed by a trained team using standard techniques.[25,28]

Blood pressure measurement and anthropometric variables

BP was measured at three different time points after 5 min of rest in a private room, with the child sitting, using an automated sphygmomanometer (Omron M17) with an appropriately sized cuff for the child's arm size placed on their right arm. Three measurements of systolic (SBP) and diastolic (DBP) BP were taken with a 2-min interval between measurements.

Weight was measured using a digital scale accurate to 0.1 kg (Seca 770), and height was measured twice using a portable stadiometer accurate to 0.1 cm (Seca 217). Waist circumference (WC) was measured twice with a flexible non-stretching tape (Seca) at the midpoint between the anterior superior iliac crest and the lowest rib. Triceps, subscapular and suprailiac skinfold thicknesses were measured using a Holtain skinfold caliper (Holtain Ltd, Crymych, UK).

Definitions of terms and groups

BP was classified according to the normative tables of the US Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents.[25] HBP was defined as SBP and/or DBP at or above the 95th percentile for age, gender and height on repeated measurement. For consistency with the Seventh Report of the US Joint National Committee on the Prevention, Detection, Evaluation, and Treatment of High Blood Pressure, BP between the 90th and 95th percentiles was classified as prehypertension.[29]

Weight status was determined using body mass index (BMI), calculated as weight in kg divided by height in m squared, considering age- and gender-specific cut-off points for classifying weight status.[30] Body fat percentage (BFP) was estimated using the equations of Slaughter et al.[31] for the triceps and subscapular skinfolds. The WC values for the 75th percentile for age and gender were used because this limit has been associated with metabolic abnormalities and cardiovascular disease risk factors in children and adolescents.[32] Similarly, values for the 75th percentile for age and gender were used as the cut-off points for BFP.

Although the three different adiposity indicators (BMI, WC, and BFP) are all associated with some degree of measurement error, each measure provides specific information regarding body fat mass.[33,34] Thus, in this study, a principal component analysis was performed with exploratory factor analysis (EFA) to obtain a construct (i.e., a factor or a latent variable) for overall adiposity based on these three anthropometric indicators, similarly to the analysis proposed by Ledoux et al.[34] Principal component analysis using the three anthropometric indicators revealed a construct representing 91% of the shared variance, with a Cronbach's alpha of 0.88 and factor loadings of 0.96 for BMI, 0.95 for WC, and 0.94 for BFP; additionally, high communalities were observed (0.93, 0.91, and 0.89, respectively). This construct was termed the adiposity index and represents overall adiposity. Higher scores from the EFA were taken to indicate higher overall adiposity. Likewise, EFA can be used to calculate a score that weights highly correlated responses, parsimoniously representing the different variables analyzed.[33]

Parents' weight status, used as a proxy to examine the effect of genetic characteristics on children's BP levels, was assessed by BMI according to the World Health Organization cut-off points[35] and based on self-reported weight and height values.

Lifestyle-related behaviors

Physical activity during leisure time was assessed according to type, frequency and duration of each activity, and the weekly time spent in each activity was estimated by multiplying the daily time (in min) by the weekly frequency. Whether the child performed a particular activity (yes/no) and the mean time spent in each activity were also ascertained and categorized into tertiles. Children's participation in physical education classes at school (yes/no) was also determined.

Time spent watching TV was assessed according to the American Academy of Pediatrics guidelines[36] and a limit of 2 h/day was considered to define excessively sedentary habits. We also asked a yes-no question about the presence of a TV set in the child's bedroom.

Statistical analysis

The statistical analyses were performed with SPSS version 20.0 (IBM SPSS Inc., Chicago, IL). The association of children's and parents' characteristics with BP classification was assessed with the chi-square test. The partial correlation coefficient was used to estimate the association between BP and anthropometric indicators (BMI, WC, BFP, and adiposity index) adjusted for gender, age, and height percentile.

Multinomial logistic regression models were used to estimate the association between exposure variables that in univariate analysis were associated with the assessed outcome with $p < 0.20$, and BP classification (dependent variable), using the categories of (1) normal (reference category), (2) high-normal BP, and (3) hypertension, i.e. the model compared the probability in the following categories (1 vs. 2 and 1 vs. 3), stratified by gender and adjusted for age and height percentile. The reference categories for the independent variables were weight status (normal weight), WC (<75th percentile), BFP (<75th percentile), adiposity index (continuous variable, with higher scores indicating higher overall adiposity), maternal excess weight (no), physical activity outside school (yes), and tertile for physical activity outside school, in h/day (third tertile).

Results

The present study was conducted with 1555 6- to 9-year-old children (50.5% female) residing in the 18 districts of mainland Portugal (mean age 7.58 years; standard deviation 1.10). The prevalence of high-normal BP and hypertension was 4.5% and 3.7%, respectively. Both high-normal BP and hypertension were significantly more prevalent among

Table 1 Characteristics of schoolchildren (n = 1555; 6-9 years old) according to the prevalence of high blood pressure.

Characteristics	BP			p[*]
	Normal	High-normal n (%)	Hypertension	
Total	1427 (91.8)	70 (4.5)	58 (3.7)	-
Child characteristics				
Gender				
Male	720 (93.4)	26 (3.4)	24 (3.1)	0.04
Female	707 (90.1)	44 (5.6)	34 (4.3)	
Mean age, years (SD)	7.58 (1.10)	7.57 (1.11)	7.29 (1.14)	0.15
Weight status				
Normal weight	1035 (93.8)	36 (3.3)	32 (2.9)	< 0.01[a]
Overweight	302 (89.9)	18 (5.4)	16 (4.8)	
Obese	90 (77.6)	16 (13.8)	10 (8.6)	
WC				
< 75th percentile	1091 (94.0)	37 (3.2)	33 (2.8)	< 0.01
≥75th percentile	332 (85.6)	31 (8.0)	25 (6.4)	
BFP				
< 75th percentile	1118 (93.8)	38 (3.2)	36 (3.0)	< 0.01
≥75th percentile	303 (85.4)	31 (8.7)	21 (5.9)	
Parent characteristics				
Paternal excess weight[b]				
No	454 (92.7)	18 (3.7)	18 (3.7)	0.85
Yes	755 (91.8)	35 (4.3)	32 (3.9)	
Maternal excess weight[b]				
No	952 (93.5)	38 (3.7)	28 (2.8)	0.01
Yes	383 (88.9)	23 (5.3)	25 (5.8)	
Child lifestyle-related behaviors				
PE classes at school				
Yes	1314 (91.9)	66 (4.6)	50 (3.5)	0.19
No	110 (90.2)	4 (3.3)	8 (6.6)	
PA outside school				
Yes	846 (93.8)	34 (3.8)	22 (2.4)	< 0.01
No	549 (89.1)	34 (5.5)	33 (5.4)	
PA outside school (h/day)				
1st tertile	540 (90.0)	32 (5.3)	28 (4.7)	0.01[a]
2nd tertile	397 (91.3)	19 (4.4)	19 (4.4)	
3rd tertile	490 (94.2)	19 (3.7)	11 (2.1)	
Time watching TV				
< 2 h/day	970 (93.4)	39 (3.8)	29 (2.8)	0.06
≥2 h/day	329 (89.6)	23 (6.3)	15 (4.1)	
TV in the child's bedroom				
Yes	534 (90.1)	34 (5.7)	25 (4.2)	0.07
No	817 (93.3)	31 (3.5)	28 (3.2)	

Blood pressure classified by age, gender and height according to the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents.[25]

BFP: body fat percentage; BP: blood pressure; PA: physical activity; PE: physical education; SD: standard deviation; WC: waist circumference.

[*] by chi-square test.

[a] p for linear trend.

[b] Excess weight: overweight + obesity.

Table 2 Partial correlation coefficient between anthropometric indicators and measures of systolic and diastolic pressures among schoolchildren (n = 1555; 6-9 years old).

BP	Anthropometric indicators			
	BMI	WC	BFP	Adiposity index
SBP	0.26	0.23	0.25	0.26
DBP	0.13	0.12	0.15	0.14

p< 0.01 for all correlations. Adjusted for gender, age, and height percentile.
The adiposity index was computed by averaging the normalized values of BMI, WC, and BFP by principal component analysis.
BFP: body fat percentage; BMI: body mass index; BP: blood pressure; DBP: diastolic blood pressure; SBP: systolic blood pressure; WC: waist circumference.

females than among males (5.6% vs. 3.4% and 4.3% vs. 3.1%, respectively, p = 0.04) (Table 1). However, the prevalence of high-normal BP and hypertension showed no significant association with age (p = 0.15). An increase in weight status was positively associated with the prevalence of high-normal BP and hypertension (p< 0.01), which was also observed for high WC (p< 0.01) and high BFP (p< 0.01) (Table 1).

There was an association between maternal excess weight and increased prevalence of high-normal BP and hypertension in children (p = 0.01); however, this association was not observed for paternal excess weight (p = 0.85). The prevalence of high-normal BP and hypertension was higher among children who did not perform physical activity during their leisure time (p< 0.01), and conversely, these prevalences decreased as the time spent in physical activity per day increased (p = 0.01 for overall trend) (Table 1). SBP and DBP were positively correlated with all anthropometric indicators (BMI, WC, BFP, and adiposity index; p< 0.01 for all) (Table 2).

Due to the significant difference in the prevalence of HBP between males and females, multinomial logistic regression analysis was stratified by gender. The risk of high-normal BP was higher for males with obesity (odds ratio [OR] 6.13, p< 0.01), high WC (OR 3.14, p = 0.01), high BFP (OR 3.06, p = 0.01), and high adiposity index (OR 1.69, p = 0.01) and the risk of hypertension was greater among males who had high adiposity index (OR 1.82, p = 0.01). The risk of high-normal BP was higher for females with obesity (OR 4.25, p = 0.01), high WC (OR 2.36, p = 0.01), high BFP (OR 2.83, p< 0.01), and high adiposity index (OR 1.67, p< 0.01). Additionally, the risk of hypertension was greater for females with overweight (OR 2.43, p = 0.03), obesity (OR 5.26, p< 0.01), high WC (OR 3.47, p< 0.01), high BFP (OR 2.29, p = 0.03), high adiposity index (OR 2.03, p< 0.01), for daughters of overweight mothers (OR 3.23, p< 0.01), and for those who did not perform physical activity during leisure time (OR 2.15, p = 0.04) (Table 3).

Discussion

High-normal BP and hypertension were prevalent among 6-9-year-old Portuguese schoolchildren. All the anthropometric indicators assessed were strongly associated with the prevalence of high-normal BP and hypertension, especially among females, as well as some lifestyle-related behaviors and maternal excess weight.

The prevalence of hypertension found among these Portuguese schoolchildren was comparable to that observed in Italian children aged 6-18 years (3.5%),[5] Spanish children aged 6-16 years (3.2% for males and 3.1% for females),[17] and Chinese children aged 7-18 years (prehypertension 3.9%, hypertension 3.3%).[16] However, the prevalence of high-normal BP and hypertension observed in the present study was lower than that observed among Canadian children aged 4-17 years (prehypertension 7.6%, hypertension 7.4%),[8] Brazilian children aged 7-17 years (high-normal BP 13.9%, hypertension 12.1%),[11] and Italian children aged 6-11.9 years (hypertension 5.2-7.8%).[18] These differences in the prevalence of HBP can be explained, in part, by the variability in procedures applied in BP measurements and categorization for children and adolescents. Furthermore, differences in the ages of the studied groups may have impaired the comparability of results, since increased age is associated with changes in BP.[5,17,21]

Adiposity was more strongly associated with HBP among children with excess weight than in those with normal weight. Similarly, Tu et al.,[37] in a cohort study of American children with a mean age of 10.2 years, found that the effect of adiposity on BP was modest in children with BMI below the 85th percentile, but above this point, the effect of adiposity on BP increased up to four-fold. This relationship highlights the effect of adiposity on BP levels.[37]

Increased BP in childhood is concerning for several reasons, one of which is that HBP predisposes children to developing cardiovascular disorders, including intermediate markers of target organ damage such as increased carotid-intima media thickness.[3,21] There is also evidence that changes in BP in childhood tend to persist into adulthood.[22,23]

The identification and treatment of children at higher risk for developing hypertension is therefore an important step in reducing the excessive burden of cardiovascular disease. Furthermore, not only does the etiology of cardiovascular disease have its roots in childhood, but the lifestyles that influence the onset of chronic disease are also acquired in early life and tend to persist into adulthood.[38]

In this context, considering that routine BP measurement is recommended after the age of three,[25] Rinaldi et al.[39] state that screening for alterations in BP among children, who are mostly asymptomatic, is fundamental to prevention and reduction of cardiovascular disease, and that the school environment is an appropriate place for measuring and monitoring BP.

A significant association has been observed in some studies between sedentary behavior and/or low levels of physical activity and HBP.[10,15,20] However, in the present study, no significant association between high-normal BP and hypertension and indicators of physical activity and sedentary behavior was observed after adjustment in the multinomial model. Similar results were observed among Italian[5] and Mexican[9] children.

Due to its cross-sectional design, the present study was unable to determine causality between adiposity and HBP among the studied children. However, similar associations have been found in longitudinal studies.[7,23,37] This study has some limitations, including the lack of information on parental BP, which could reflect the genetic origin of cardiovascular disorders.[5,21] However, Tringler et al.[15] found no significant association between hypertension in children and parental hypertension (p = 0.35). In the present study, in the absence of such information, parental BMI was used as a proxy to examine the effect of parental characteristics on children's BP levels. Similar results were observed among five-year-old Australian children.[40]

The analyses in this study represent a breakthrough in the understanding of the impact of adiposity on BP levels in schoolchildren after controlling for possible influencing factors. An unexpectedly high prevalence of high-normal BP and hypertension was observed among Portuguese schoolchildren. Higher values for body fat indicators were strongly associated with HBP, reinforcing the usefulness of these indicators in screening for health problems among children, and specifically the risk of elevated BP levels. Prevention of childhood obesity is therefore of paramount importance to reduce the risk of HBP and cardiovascular disease.

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Ethics approval and consent to participate

The PPSOC was approved by the Directorate-General for Curriculum Innovation and Development of the Portuguese Ministry of Education. Additionally, authorization for data collection was obtained from the schools, and the participants' parents or guardians signed a consent form indicating their agreement to participate.

Table 3 Risk of high-normal blood pressure and hypertension among Portuguese schoolchildren estimated with multinomial regression models (n = 1555; 6-9 years old).

Anthropometric indicators	Males				Females			
	High-normal BP		Hypertension		High-normal BP		Hypertension	
	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p	OR (95% CI)	p
Weight status								
Normal weight	1		1		1		1	
Overweight	2.34 (0.88-6.26)	0.09	1.26 (0.40-3.97)	0.69	1.28 (0.60-2.74)	0.53	2.43 (1.08-5.47)	0.03
Obesity	6.13 (2.03-18.52)	< 0.01	3.40 (0.87-13.36)	0.08	4.25 (1.84-9.83)	< 0.01	5.26 (1.95-14.15)	< 0.01
WC								
< 75th percentile	1		1		1		1	
≥75th percentile	3.14 (1.30-7.58)	0.01	2.51 (0.96-6.57)	0.06	2.36 (1.19-4.67)	0.01	3.47 (1.63-7.41)	< 0.01
BFP								
< 75th percentile	1		1		1		1	
≥75th percentile	3.06 (1.27-7.41)	0.01	2.56 (0.99-6.58)	0.05	2.83 (1.48-5.42)	< 0.01	2.29 (1.08-4.86)	0.03
Adiposity index[a]								
Score	1.69 (1.15-2.49)	0.01	1.82 (1.15-2.86)	0.01	1.67 (1.20-2.31)	< 0.01	2.03 (1.41-2.92)	< 0.01
Maternal excess weight[b]								
No	1		1		1		1	
Yes	1.54 (0.62-3.79)	0.35	1.28 (0.51-3.21)	0.60	1.33 (0.68-2.59)	0.41	3.23 (1.55-6.75)	< 0.01
PA outside school								
Yes	1		1		1		1	
No	1.78 (0.80-3.99)	0.16	2.19 (0.94-5.12)	0.07	1.33 (0.72-2.47)	0.36	2.15 (1.03-4.47)	0.04
PA outside school (h/day)								
1st tertile	1.68 (0.66-4.27)	0.28	1.49 (0.55-4.03)	0.43	1.29 (0.61-2.75)	0.50	2.99 (1.00-8.99)	0.05
2nd tertile	1.25 (0.44-3.55)	0.67	1.19 (0.41-3.51)	0.75	1.13 (0.49-2.63)	0.77	3.02 (0.96-9.56)	0.06
3rd tertile	1		1		1		1	

Blood pressure classified by age, gender and height according to the Fourth Report on the Diagnosis, Evaluation and Treatment of High Blood Pressure in Children and Adolescents.[25]
The multinomial logistic regression model was stratified by gender and adjusted for age and height percentile.
The group with normal blood pressure was the reference category for the high blood pressure groups.
[a] Continuous variable: higher scores indicate higher overall adiposity.
[b] Excess weight: overweight + obesity.
BP: blood pressure; BFP: body fat percentage; CI: confidence interval; OR: odds ratio; PA: physical activity; WC: waist circumference.

Authors' contributions

PRMR contributed to analysis and interpretation of data, the drafting, writing, and revision of the manuscript, and final approval of the manuscript. RAP contributed to analysis and interpretation of data, critical revision of the manuscript, and final approval of the manuscript. AG, IMC, HN, and VRM contributed to the design of the data collection instruments, review and revision the manuscript, and final approval of the manuscript. CP contributed to the conception and design of the study, coordination and supervision of data collection, review and revision of the manuscript, and final approval of the manuscript.

Conflicts of interest

The authors have no conflicts of interest to declare.

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