ORIGINAL ARTICLE

Overweight and Blood Pressure in Pre-Pubertal Children: A Longitudinal Study

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ABSTRACT

Objectives: To analyze the longitudinal relationship between overweight and hypertension in school children.

Methods: This cohort study enrolled children 6-8 years of age who were then prospectively followed up over a 24 months period with repeat assessments performed at an interval of 11-13 months. Information on participation in physical education classes in school, sports practice outside of school, and economic status were obtained through questionnaires answered by parents/guardians. The measurement of blood pressure, weight, height, and waist circumference was performed during the serial follow-up visits in school.

Results: The proportion of hypertension did not change significantly over the 24 months (7.1% to 8.2%; $P = 0.690$). However, children with overweight and obesity throughout the period, had a 198% [HR (95% CI) 2.98 (1.40, 6.35)] higher risk of having hypertension diagnosed during follow-up when compared to eutrophic children in the same period.

Conclusions: The development trajectory of overweight and obesity in children aged 6-8 years was associated with hypertension.

Keywords: *Adiposity, Hypertension, Physical activity, Risk factors*

Published online: March 05, 2024; ***PII***: S097475591600604

INTRODUCTION

Cardiovascular diseases are the leading cause of death in adults worldwide, with more than three-quarters occurring in low- and middle-income countries [1]. Arterial hypertension, characterized by increased resting blood pressure, is one of the main cardiovascular diseases in adulthood [2]. In 2013, the prevalence of high blood pressure reached 15% in Brazilian children [3]. Hypertension tracks from early life to adulthood, increasing the risk of other cardiovascular diseases and early mortality [4].

Childhood obesity is one of the main determinants of high blood pressure in early life [5]. In 2020, 39 million children were diagnosed with obesity around the world [6]. The current understanding of the association between hypertension and childhood obesity is limited by a few cross-sectional studies in older children and adolescents [4,7]. The main objective of this study was to analyze the association between overweight and hypertension in 6 to 8-year-old children longitudinally.

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Received: July 20, 2023; Initial review: July 28, 2023;
Accepted: Feb 07, 2024

METHODS

This prospective study was carried out in the city of Presidente Prudente and was approved by the Ethical Board of the University of Western São Paulo. Presidente Prudente is in the western region of the State of São Paulo, Brazil and is characterized as the largest city in the region with about 200,000 inhabitants. The municipality administration (Department of Education) is responsible for running 29 primary schools in the city (grade 1 to 5) catering to children aged 6-11 years, that were invited to participate in the study.

The children aged 6-8 years were enrolled after an informed written consent from parents/legal guardians. Children were prospectively followed up at three time points, wherein measurements intervals ranged from 11 to 13 months, *viz* at August-December, 2016, 2017, and 2018. The research project was cancelled in 2019 during

the COVID-19 pandemic. All variables described below were measured at the aforementioned three-time points. The research team responsible for the anthropometric measurements comprised of two researchers, two physical education teachers, and two undergraduate students (pursuing the course of Physical Education) who were previously trained to take these measurements.

Blood pressure was measured by the auscultatory method, in accordance with the guidelines by the Brazilian Society of Cardiology [8]. Systolic (SBP) and diastolic (DBP) blood pressure were measured three times using sphygmomanometers (Premium brand, Hospitalar mesa/paredemodel). Measurements were obtained in the right arm, with the child in the sitting position, after a minimum of five minutes of rest (first measurement) by a trained team of seven undergraduate students. Hypertension was identified using the recommended cut-off points [8], which were adjusted for age, sex, and height percentiles.

Weight was measured on a digital scale (G-tech brand, Glass 10 model) with an accuracy of 0.1 kg, and height was determined on a wooden stadiometer with an accuracy of 0.1 cm, according to standardized procedures [9]. All measurements were recorded twice and a third observation was performed in case of discrepancy to adopt a mean value. Waist circumference (WC) was measured using a non-elastic tape with a 0.1 cm scale following standard procedure [9]. All measurements were performed with the children wearing light clothes (t-shirts and shorts/shorts) and barefoot. Considering percentiles adjusted for age and sex, overweight and obesity (Ow/Ob) were diagnosed when body mass index (BMI) values were ≥ 85th (overweight) and ≥ 95th (obesity) centiles, respectively [10].

Covariates considered in the statistical models, were sex, age, economic status, height, and sports participation. Economic status was assessed using a standard questionnaire completed by the parents/legal guardians [11]. Sports participation was reported by the parents/legal guardians considering the following question: "Over the past 12 months, was your child engaged in any sports activity, outside school and supervised by a professional (coach)?" [12]. Adherence to school physical education classes was also recorded.

Statistical analyses: Descriptive statistics consisted of mean values and standard deviation. Pearson correlation (*r*) was used to analyze the relationship between the numerical variables. The analysis of variance for repeated measures (ANOVA) compared numerical variables over the time of follow-up (adjusted by covariates). Associations were assessed by the Chi-square test and their magnitudes were expressed as hazard ratio (HR) and 95% CI by Cox regression (adjusted for sex, age, height, economic status, and sports engagement). *P* value < 0.05 was considered statistically significant. All analyses were run in the statistical software BioEstat (version 5.0, Tefé, Amazonas).

RESULTS

All the 29 schools were approached; of which 26 were willing to participate. Out of 1452 children whose parents/guardians were approached, 753 (51.5%) consented to participate in the study. The flow of the study participants is shown in **Fig. 1**. Sex distribution was similar in all stages of the study (Baseline: 280 boys and 298 girls; 12-months: 218 boys and 225 girls; 24-months: 132 boys and 124 girls). The general characteristics of the 256 children (132 boys, 124 girls) who completed follow-up over 24 months are presented in **Table I**.

The increase in WC and BMI were related to a significant increase in SBP and DBP, regardless of sex after adjusting for covariates (age at baseline, economic status, and sports engagement throughout follow-up) (**Table II**). As compared to children who were Not diagnosed with Overweight/Obesity during the 24-month follow-up, children with the presence of Overweight/Obesity in all assessments presented an increased risk of having hypertension (**Table III**). For each 1 kg/m² increase in BMI, there was an increase of 1.93 mmHg in SBP and 1.44 mmHg in DBP.

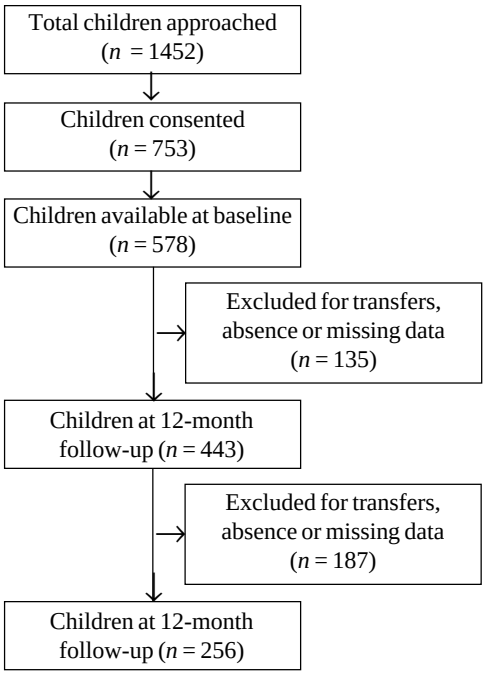

Fig.1 Flow of study participants during follow-up

Table I Characteristics of the Children who Completed Evaluation Over 24-months Follow-up (*n* = 256)

	Baseline	*12 months*	*24 months*
Chronological age[a] (y)	7.4 (0.6)	8.4 (0.5)	9.5 (0.5)
Body weight[a] (kg)	28.6 (7.7)	32.4 (9.2)	37.6 (11.2)
Height[a] (cm)	1.27 (0.06)	1.33 (0.07)	1.39 (0.07)
BMI[a] (kg/m^2)	17.3 (3.4)	17.9 (3.7)	19.1 (4.2)
WC[a] (cm)	59.7 (8.1)	62.2 (9.2)	65.6 (10.7)
SBP[a] (mmHg)	89.9 (9.9)	93.8 (10.2)	92.3 (11.6)
DBP[a] (mmHg)	57.9 (10.1)	61.5 (9.2)	61.3 (9.7)
Overweight[b] *n* (%)	89 (34.8%)	96 (37.5%)	118 (46.1%)
Hypertension, *n* (%)	18 (7.1%)	29 (11.3%)	21 (8.2%)
Sports participation, *n* (%)	55 (21.5%)	61 (23.8%)	62 (24.2%)
PE classes[b], *n* (%)	177 (69.1%)	222 (86.7%)	223 (87.1%)

Data expressed as mean and standard deviation (SD); BMI body mass index; WC waist circumference; SBP systolic blood pressure; DBP diastolic blood pressure; PE classes physical education classes [a]P value < 0.05 for analysis of variance for repeated measures (Baseline versus 24 months); [b]P value < 0.05 for Chi-square test (linear-by-linear association)

DISCUSSION

The present study showed an increased risk of developing hypertension in children with persistent overweight/obese status at 24 months follow-up. The prevalence of hypertension in this study was 7%, which is lower than that observed in Europe (22.8%) [13], Australia (12.6%) [14] and China (6.1 - 9.4%) [15]. This may be attributed to the sample of younger children in this study and other factors such as geographic factors, maturation, nutritional status, and level of physical activity [16].

BMI is an anthropometric index associated with hypertension, regardless of genetic, social, and geographic factors [5]. During follow-up in this study, children who were overweight/obese at baseline had a higher risk of hypertension during the follow-up. BMI is recognized as a determinant of blood pressure in pediatric age groups [17]. The association between obesity and hypertension relies on peripheral vascular resistance [4]. The peripheral vascular resistance attributed to obesity relies on sympathetic hyperactivity and insulin resistance generated by obesity, which decreases sodium excretion and impairs vascular reactivity [18]. Other indirect factors such as the presence of low-grade inflammation and the consumption of a diet rich in lipids, sodium, and sugars are also implicated [17,18].

Table II Relationship Between Changes in Anthropometric Indices and Changes in Blood Pressure Among Children

	Total (n= 256)	*Boys (n= 132)*	*Girls (n= 124)*
SBP			
BMI (kg/m^2)	1.93 (1.22, 2.65)	2.35 (1.44, 3.27)	1.21 (0.01, 2.42)
WC (cm)	0.61 (0.37, 0.86)	0.68 (0.38, 0.99)	0.50 (0.06, 0.94)
DBP			
BMI (kg/m^2)	1.44 (0.72, 2.16)	1.17 (0.21, 2.12)	1.91 (0.76, 3.06)
WC (cm)	0.41 (0.17, 0.66)	0.34 (0.03, 0.66)	0.61 (0.18, 1.03)

Values expressed as β (95% CI); model adjusted for age at baseline, economic status, and sport engagement throughout follow-up; All correlations were statistically significant at P value < 0.05
Model summary: SBP and BMI in boys r^2= 0.18 and girls r^2= 0.07; DBP and BMI in boys r^2= 0.05 and girls r^2= 0.09; SBP and WC in boys r^2= 0.14 and girls r^2= 0.08; DBP and WC in boys r^2= 0.04 and girls r^2= 0.07 BMI Body mass index; WC Waist circumference; SBP Systolic blood pressure; DBP Diastolic blood pressure

The association of physical exercise and blood pressure control is unclear in children [19]. Sports participation and physical education classes did not affect blood pressure in this study, similar to an earlier study in adolescents [20]. However, sports participation improves parasympathetic indices [20], in the absence of changes in blood pressure.

Table III Association Between Overweight/Obesity Trajectory Over 24 Months With Hyperytension

Ow/Ob Trajectory	*Hypertension detected on at least one of the assessments n (%)*	*Hazard Ratio (95% CI)*
Normal Wt (*n* = 129)	15 (11.6%)	1.00
New Ow/Ob on Follow-up (*n* = 9)	02 (22.2%)	1.91 (0.35, 10.36)
New Normal-Wt on Follow-up (*n* = 38)	07 (18.4%)	1.29 (0.46, 3.65)
Persistent Ow/Ob (*n* = 80)	28 (35.1%)	2.98 (1.40, 6.35)

Normal-Wt Normal-weight in all analyses, New-Ow/Ob Became overweight/obese at follow-up, New Normal-Wt No longer overweight/obese at follow-up, Persistent Ow/Ob Overweight/obese at all time points

WHAT THIS STUDY ADDS?

- An increased risk of hypertension was seen in young children (6-8 years) who developed or persisted to have overweight/obesity at the end of two years follow-up.

The limitations of this study include the fact that the volume and intensity of sports practice outside the school environment and school physical education classes were not measured. Additionally, sedentary behavior, diet, or parental history of hypertension, were not evaluated. We did not exclude a pre-existing diagnosis of chronic diseases and use of any regular medicines.

In summary, the prevalence of overweight/obesity prevalence increased significantly during the study period. This is concerning as overweight/obesity was shown to be linked to an increased risk of hypertension even in children aged 6 to 8 years of age over a two-year period.

Ethical clearance: The study was approved by the Ethics Research Committee of the University of Western São Paulo (UNOESTE [CAAE nº 51996615.0.0000.5515 protocol number 3008] dated March 23, 2016).

Contributors: MJA and RAF: Study concept, data collection, design, and ethics applications; WT, AEVAM, CACF, RCC, DGDC, JC, and LCMV: Conception, acquisition of data, analysis, interpretation of data, revising the manuscript critically. All authors approved the final manuscript.

Funding: CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico), CAPES (Coordenação de Aperfeiçoamento de Pessoal de Nível Superior – Brasil [FinanceCode 001]) and FAPESP (Fundação de Amparo à Pesquisa do Estado de São Paulo RAF [Process: 2022/09796-1], and WT [Process: 2021/08655-2]).

Competing interest: None stated.

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