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Research Article

Anthropometric determinants of high blood pressure in elementary schoolchildren

Determinantes antropométricos da pressão arterial elevada em escolares do ensino fundamental

Determinantes antropométricos de la presión arterial alta en escuelas de educación fundamental

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ABSTRACT

Introduction: Pediatric hypertension has received special attention from pediatricians, as increased blood pressure in childhood contributes to the early onset of essential hypertension in adulthood and mortality from cardiovascular diseases. Anthropometric measurements have been useful in diagnosing childhood overweight and obesity, considered risk conditions for hypertension in adulthood. The earlier the identification of these risk factors, whether in the school environment or in health services, the higher the number of preventive actions that can be developed to reduce this problem. **Objective:** To identify the incidence of high blood pressure and its association with anthropometric measurements in elementary schoolchildren. **Methods:** This is a longitudinal study with 1,116 schoolchildren, 133 of whom participated in three assessments from 2017 to 2019. Demographic information, anthropometric measures (weight, height, waist circumference, body mass index), and blood pressure values (systolic and diastolic adjusted for sex and age according to parameters from the Centers for Disease Control and Prevention) were recorded in a form. The association of variables with high blood pressure was analyzed using Poisson regression, with robust variance adjustment. **Results:** A total of 51.6% of students were boys with a mean age of 7.9 years, and 45.4% had high blood pressure according to criteria from the Centers for Disease Control and Prevention. Among those who presented high waist circumference, 19.4% progressed from normal to high systolic blood pressure, and 35.5% from normal to high diastolic blood pressure over the three years of follow-up. In overweight and obese schoolchildren, normal systolic blood pressure progressed to high in 20.7 and 21.2% of cases, respectively, and normal diastolic blood pressure progressed to high in 24.1 and 42.4%, respectively. Schoolchildren with high waist circumference (relative risk – RR 1.51; confidence interval – 95%CI 1.20–1.91; RR 1.58; 95%CI 1.25–2.00), weight (RR 1.37; 95%CI 1.08–1.74; RR 1.34; 95%CI 1.05–1.71), and body mass index (RR 1.51; 95%CI 1.21–1.87; RR 1.50; 95%CI 1.20–1.88) presented a greater risk for systolic and diastolic hypertension, respectively. **Conclusions:** Waist circumference, weight, and body mass index were associated with increased systolic and diastolic blood pressure in schoolchildren, and the risk was greater among those with higher waist circumference.

Keywords: Child; Overweight; Pediatric obesity; Hypertension; Cardiovascular diseases.

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RESUMO

Introdução: A hipertensão arterial infantil vem recebendo atenção especial dos pediatras, pois o aumento da pressão arterial na infância contribui para o início precoce da hipertensão arterial essencial na idade adulta e para a mortalidade por doenças cardiovasculares. As medidas antropométricas têm sido úteis para o diagnóstico de sobrepeso e obesidade na infância, e tais condições são consideradas de risco para hipertensão arterial na idade adulta. Quanto mais precoce a identificação desses fatores de risco, seja no ambiente escolar, seja nos serviços de saúde, mais ações preventivas poderão ser desenvolvidas para minimizar tal problemática. **Objetivo:** Identificar a incidência de pressão arterial elevada e sua associação com medidas antropométricas em escolares do ensino fundamental. **Métodos:** Estudo longitudinal com 1.116 escolares; destes, 133 participaram de três avaliações no período de 2017 a 2019. As informações demográficas, as medidas antropométricas (peso, altura, circunferência abdominal, índice de massa corporal) e as pressóricas (sistólica e diastólica ajustadas de acordo com os parâmetros do Centro de Controle e Prevenção de Doenças para sexo e idade) foram registradas em formulário. A associação das variáveis com a pressão arterial elevada foi analisada por meio da regressão de Poisson, com ajuste robusto da variância. **Resultados:** Dos estudantes, 51,6% eram meninos com, em média, 7,9 anos, e 45,4% tinham pressão arterial elevada conforme os critérios do Centro de Controle e Prevenção de Doenças. Entre os que apresentaram circunferência abdominal elevada, 19,4% evoluíram de pressão sistólica normal para elevada e 35,5% de pressão diastólica normal para elevada ao longo dos três anos de acompanhamento. Nos escolares com sobrepeso ou obesidade, a pressão sistólica normal evoluiu para elevada em 20,7 e 21,2%, respectivamente, e a pressão diastólica normal evoluiu para elevada em 24,1 e 42,4%, respectivamente. Os escolares com circunferência abdominal (risco relativo – RR 1,51; intervalo de confiança – IC95% 1,20–1,91; RR 1,58; IC95% 1,25–2,00), peso (RR 1,37; IC95% 1,08–1,74; RR 1,34; IC95% 1,05–1,71) e índice de massa corporal elevado (RR 1,51; IC95% 1,21–1,87; RR 1,50; IC95% 1,20–1,88) apresentaram maior risco para hipertensão sistólica e diastólica, respectivamente. **Conclusão:** A circunferência abdominal, o peso e o índice de massa corporal estiveram associados com o aumento da pressão arterial sistólica e diastólica nos escolares, e o risco foi maior entre os que tinham circunferência abdominal aumentada.

Palavras-chave: Criança. Sobrepeso. Obesidade pediátrica. Hipertensão. Doenças cardiovasculares.

RESUMEN

Introducción: La hipertensión arterial infantil ha recibido especial atención por parte de los pediatras, ya que el aumento de la presión arterial en la infancia contribuye a la aparición precoz de la hipertensión arterial esencial en la edad adulta y la mortalidad por enfermedades cardiovasculares. Las mediciones antropométricas han sido útiles para el diagnóstico de sobrepeso y obesidad en la infancia, y estas condiciones se consideran un riesgo de hipertensión arterial en la edad adulta. Cuanto antes se identifiquen estos factores de riesgo, ya sea en el ámbito escolar o en los servicios de salud, más acciones preventivas se pueden desarrollar para minimizar este problema. **Objetivo:** Identificar la incidencia de hipertensión arterial y su asociación con medidas antropométricas en estudiantes de primaria. Métodos: Estudio longitudinal con 1.116 estudiantes; de estos, 133 participaron en tres evaluaciones de 2017 a 2019. Información demográfica, medidas antropométricas (peso, talla, circunferencia de cintura, índice de masa corporal) y presión arterial (sistólica y diastólica ajustadas según los parámetros del Centro de Control y Prevención de Enfermedades, por sexo y edad) se registraron en un formulario. La asociación de variables con hipertensión arterial se analizó mediante regresión de Poisson con ajuste de varianza robusto. **Resultados:** El 51,6% de los estudiantes era var**ón** con un promedio de 7,9 años y el 45,4% presentaba hipertensión arterial, según los criterios del Centro para el Control y la Prevención de Enfermedades. Entre los que tenían una circunferencia de cintura alta, el 19,4% evolucionó de presión sistólica normal a alta y el 35,5% de presión diastólica normal a alta durante los tres años de seguimiento. En escolares con sobrepeso u obesidad, la presión sistólica normal evolucionó a alta en un 20,7% y un 21,2%, respectivamente, y la presión diastólica normal evolucionó a alta en un 24,1% y un 42,4%, respectivamente. Estudiantes con circunferencia de cintura (RR 1,51; IC95% 1,20–1,91; RR 1,58; IC95% 1,25–2,00), peso (RR 1,37; IC95% 1,08–1,74; RR 1,34; IC95% 1,05–1,71) y alto índice de masa corporal (RR 1,51; IC95% 1,21–1,87; RR 1,50; IC95% 1, 20–1,88) tenían un mayor riesgo de hipertensión sistólica y diastólica, respectivamente. **Conclusiones:** La circunferencia de la cintura, el peso y el índice de masa corporal se asociaron con un aumento de la presión arterial sistólica y diastólica en los escolares y el riesgo fue mayor entre los que tenían una mayor circunferencia de la cintura.

Palabras-clave: Niño. Sobrepeso. Obesidad pediátrica. Hipertensión. Enfermedades cardiovasculares.

INTRODUCTION

Identifying pediatric hypertension is quite important for public health since increased blood pressure (BP) in childhood contributes significantly to mortality from cardiovascular diseases in adulthood.[1] Studies indicate that atherosclerotic changes,[1,2] as well as left ventricular hypertrophy[3] and myocardial dysfunction,[3] may start in childhood. In addition, high BP in childhood is a predictor of hypertension in adulthood.[2] Therefore, failure in diagnosing hypertension in childhood delays the start of treatment, contributing to its persistence until adulthood and increasing the prevalence of disease repercussions, as the duration of hypertension is related to the risk of damage to target organs.[4]

In recent decades, the prevalence of hypertension in children and adolescents has increased.[4] Meta-analysis of studies carried out in Africa found a prevalence of 12.7% pre-hypertension and 5.5% hypertension in children and adolescents aged 2–19 years,[5] results consistent with those of an investigation conducted in the United States with 3–18-year-olds, of whom 10.1% had pre-hypertension and 3.3% had hypertension.[6] However, another research performed in the United States identified a 38% increase in the prevalence of pre-hypertension and hypertension in children and adolescents aged 8–17 years, more frequent in boys (19.2%) than in girls (12.6%).[7] In Europe, the prevalence of hypertension in this population ranges from 2.2 to 22.0%.[8] In Brazil, a school-based study revealed that 9.6% of adolescents had hypertension, and this condition was more frequent in the Southern region of the country (12.5%).[9] The prevalence variability found in the studies is explained by differences in the measurement method, including the type of device used and the number of measurements taken, as well as some characteristics of the population, for example, obese participants.[5,8]

Several risk factors are associated with hypertension in children and adolescents, with overweight being the most consistently documented in the genesis of this disease.[9] Many studies have shown that the prevalence of hypertension in children and adolescents is growing in parallel with the global increase in the prevalence of overweight and obesity in these life stages.[9,10] According to data from the Food and Nutrition Surveillance System (*Sistema de Vigilância Alimentar e Nutricional* — SISVAN), 15.7% of Brazilian children aged 5–10 years are overweight, and 8.9% are obese; specifically in Espírito Santo, 16.2 and 8.7% of children in this age group are overweight and obese, respectively.[11] As for Brazilian adolescents, 19.3% are overweight, and 9.4% are obese.[11] A cross-sectional study with 4,609 schoolchildren from the municipality of Maringá analyzed the prevalence of obesity and its association with the increase in BP and identified that high or borderline BP among overweight students was almost twice more prevalent than in those with normal weight.[12]

As a consequence, overweight-related hypertension in adolescence has been increasingly investigated since this association means a potential increase in the risk of cardiovascular disease compared to other risk factors alone.[13] In this scenario, anthropometry is widely used to assess children's nutritional status in health services, given its advantages: low cost, simple execution, easy application and standardization, and range of the analyzed aspects, besides not being invasive.[14] Still, the literature disagrees on the magnitude of the associations between different anthropometric measurements and cardiometabolic risk in children.[15] The association between visceral fat, evaluated by waist circumference (WC), and BP has been extensively studied in adults, showing that the growth in WC increases BP.[16] Nevertheless, despite the evidence of this relationship in adults, only recently has this association been investigated in children.[17]

A study investigating 38,810 Chinese students — children and adolescents — with low body mass index (BMI) and high WC indicated an increased risk of hypertension for this population, which would have been underestimated if only BMI was considered.[18]On the other hand, studies have reported a strong correlation between the increase in child BMI percentile and the risk of hypertension.[19]

Considering that the early diagnosis of pediatric hypertension is important to reduce morbidity and mortality from cardiovascular diseases in adulthood and that anthropometric measurements, accessible and easy to perform, can be very useful tools for identifying overweight and obesity, the present study aimed to find the incidence of hypertension in schoolchildren from an elementary school over three years, as well as analyze its association with BMI and WC, which can predict the risk for hypertension.

METHODS

This longitudinal study was carried out in a municipal public elementary school in the city of Vila Velha, Espírito Santo, Brazil. Follow-ups were conducted for three years (2017–2019) by a group of selected and trained medical students participating in the outreach project "*Saúde na Escola: um projeto de pesquisa-intervenção*" (Health at School: a research-intervention project). The school was chosen by convenience, considering that data from another outreach project in the same school were used.

The sample consisted of all regularly enrolled schoolchildren whose parents agreed to their participation in the outreach project (n=1,422).

Sample loss was 21.5%, corresponding to students who did not have their BP, WC, weight, or height measurements recorded in any of the three years (n=306). Sample power was 100% for a type I error <5%, high blood pressure incidence was 55% for exposed participants and 39% for non-exposed ones, and the incidence ratio was 1.4.

A form was prepared for the annual record of the students' information, including anthropometric measurements, BP, and other health aspects. The sociodemographic data included in the questionnaire were sex, age, and ethnicity.

The variables used in this study were: age in years and ranges (6–7; 8–9; 10–12); ethnicity (white; non-white); weight in grams, classified according to sex and age (low; appropriate; high); WC in centimeters, classified according to sex and age (appropriate; high); BMI in kg/m^2, classified according to sex and age (underweight; normal weight; overweight; obesity); systolic blood pressure (SBP) and diastolic blood pressure (DBP) in mmHg, classified according to sex, age, and height score (normal; high).

Weight was measured in a portable electronic scale (Líder brand), with capacity for up to 200 kg and readability of 50 g, calibrated and certified by the National Institute of Metrology, Standardization and Industrial Quality (*Instituto Nacional de Metrologia, Qualidade e Tecnologia* — Inmetro). The student was asked to remove their shoes, coat, and possible accessories and then stand with both feet in the middle of the scale, hands along their body, and looking forward. Weight was recorded to the nearest decimal fraction and categorized according to SISVAN,[14] using weight charts for age and sex. The classification adopted was:

1. Underweight: less than the 3rd percentile;
2. Normal weight: greater than or equal to the 3rd percentile and less than the 97th percentile;
3. High: greater than or equal to the 97th percentile.[19]

Height was measured with a wall stadiometer (MD brand), with a measuring range of 0 to 200 cm and 1 mm graduation. The student remained without shoes, bulky clothes, or hair accessories, standing upright, with their back to the vertical rod of the stadiometer. Buttocks, scapula, and head were placed in contact with the stadiometer tape, with the arms along the body and the palms facing the lower limbs and thighs. The student's head was held in the Frankfurt horizontal position, while the examiner lowered the horizontal bar firmly to the head crown with enough pressure to compress the hair.[14] Height was individually categorized based on percentile for later use in BP classification, following SISVAN guidelines.[14]

WC was measured by a non-elastic measuring tape, graduated in millimeters, placed at the midpoint between the last rib and the iliac crest.[20] Students with values greater than or equal to the

90^{th} percentile, according to sex and age, were considered as having high WC, while those below this percentile were considered as having appropriate WC, based on cut-off points proposed by Freedman et al.[20]

BMI was calculated using body weight (kg) as the numerator and height (m^2) as the denominator and classified according to tables and charts standardized for sex, age, height, and weight, as defined by SISVAN.[14] Schoolchildren classified as underweight were below the 3^{rd} BMI percentile; normal-weight children had a BMI greater than or equal to the 3^{rd} percentile and less than the 85^{th}; overweight children had a BMI greater than or equal to the 85^{th} percentile and less than the 97^{th} percentile; obese children had a BMI greater than or equal to the 97^{th} percentile.[14]

BP was obtained using the auscultatory technique, with an aneroid sphygmomanometer properly calibrated, whose cuff was suitable for the circumference of the student's arm, and a stethoscope placed on the pulse of the brachial artery, proximal and medial to the cubital fossa and below the lower edge of the cuff.[21] Students were called to have their BP measured before recess and at times far from physical education classes, instructed to remain at rest for 5 minutes and to sit in a calm environment, with legs uncrossed and feet on the ground, back resting in the chair, arm supported at the same height of the heart, palm upturned, and elbow slightly flexed, following the guidelines of the fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents.[21] SBP was determined at the appearance of Korotkoff sounds (phase I) and DBP at their disappearance (phase V). BP was classified according to the height, age, and sex percentile, given its relationship with body size.[14] Thus, the student was considered normotensive when their BP was below the 90^{th} percentile and as having high BP when greater than or equal to the 90^{th} percentile. The measurement was repeated on at least two other occasions to confirm the diagnosis.[21]

Questionnaire information was entered into Microsoft Excel®, and statistical analyses were conducted in the Stata statistical software, version 13.0 (StataCorp LP, College Station, United States). Students who participated in at least one of the follow-ups and had all their data recorded were selected (n=1,116). Variables were stratified by sex. However, the only difference between sexes was related to age, so the association analysis was not performed separately. The chi-square test of heterogeneity was adopted for categorical variables, with the result expressed as simple and relative frequency. Numerical variables were presented as mean and standard deviation after application of Student's *t*-test. Poisson regression with robust variance adjustment was used to verify the risk ratio of SBP and DBP to exploratory variables, considering a 95% confidence interval (95%CI).

The informed consent form was approved by the Research Ethics Committee of Universidade Vila Velha (opinion no. 1,751,120), given to the students, and signed by their parents or guardians. The school administration provided an authorization form for the performance of the project. The study was registered in Plataforma Brasil (registration no. 79143417.0.0000.5064) and started after knowledge and consent from the school and parents or guardians.

RESULTS

Out of 1,116 schoolchildren, most were boys (51.6%), with a mean age of 7.9 years, and non-white ethnicity (66.4%). For every five students followed, one had high weight and/or WC, and about two were overweight or obese according to BMI. A quarter of students had high SBP or DBP. The only difference between boys and girls was related to age, as girls were younger (p=0.008) (Table 1).

Table 1. Distribution of schoolchildren stratified by sex, according to age, ethnicity, weight, waist circumference, body mass index, systolic and diastolic blood pressure, Vila Velha (ES), 2017 to 2019 (n=1,116)

	Male		**Female**		**Total**		**p-value**
	n=576		**n=540**		**n=1,116**		
Age (years)	8.1±1.5		7.8±1.4		7.9±1.5		0.008*
6–7	234	40.6% (36.7–44.7)	251	46.5% (42.3–50.7)	485	43.4% (40.6–46.4)	
8–9	214	37.2% (33.3–41.2)	189	35.0% (31.1–39.1)	403	36.1% (33.3–39.0)	0.110†
10–12	128	22.2% (19.0–25.8)	100	18.5% (15.4–22.0)	228	20.4% (18.2–22.9)	
Ethnicity‡							
White	139	34.0% (29.5–38.7)	129	33.2% (28.6–38.0)	268	33.6% (30.4–36.9)	0.822†
Non-white	270	66.0% (61.3–70.5)	260	66.8% (62.0–71.4)	530	66.4% (63.0–69.6)	
Weight (kg)	31.4±9.5		31.4±10.4		31.4±9.9		0.931*
Low	10	1.7% (0.9–3.2)	6	1.1% (0.5–2.4)	16	1.4% (0.9–2.3)	
Appropriate	453	78.7% (75.1–81.8)	422	78.2% (74.4–81.4)	875	78.4% (75.9–80.7)	0.630†
High	113	19.6% (16.6–23.1)	112	20.7% (17.5–24.4)	225	20.2% (17.9–22.6)	
WC (cm)	63.2±24.7		61.5±10.4		62.4±19.2		0.145*
Appropriate	460	79.9% (76.4–82.9)	435	80.6% (77.0–83.7)	895	80.2% (77.7–82.4)	0.822†
High	116	20.1% (17.0–23.6)	105	19.4% (16.3–23.0)	221	19.8% (17.6–22.2)	
BMI (kg/m²)	17.6±3.4		17.7±3.7		17.6±3.5		0.618*
Underweight	28	4.9% (3.4–6.9)	15	2.8% (1.7–4.6)	43	3.9% (2.9–5.2)	
Normal weight	316	54.9% (50.8–58.9)	325	60.2% (56.0–64.2)	641	57.4% (54.5–60.3)	0.076†
Overweight	103	17.8% (14.9–21.2)	101	18.7% (15.6–22.2)	204	18.3% (16.1–20.7)	
Obesity	129	22.4% (19.2–26.0)	99	18.3% (15.3–21.8)	228	20.4% (18.2–22.9)	
SBP (mmHg)	99.3±13.8		101.7±58.9		100.5±42.2		0.360*
Normal	446	77.4% (73.8–80.7)	413	76.5% (72.7–79.9)	859	77.0% (74.4–79.3)	0.722†
High	130	22.6% (19.3–26.2)	127	23.5% (20.1–27.3)	257	23.0% (20.6–25.6)	
DBP (mmHg)	65.0±10.9		65.4±27.8		65.2±20.8		0.753*
Normal	457	79.4% (75.8–82.5)	410	75.9% (72.1–79.3)	867	77.7% (75.1–80.0)	0.173†
High	119	20.6% (17.5–24.2)	130	24.1% (20.6–27.9)	249	22.3% (20.0–24.8)	

WC: waist circumference; BMI: body mass index; SBP: systolic blood pressure; DBP: diastolic blood pressure. *t-test; †chi-square test; ‡variable not included in the 2017 follow-up (n=798).

Table 2 presents the changes in SBP classification in 133 students followed in two moments (2017 and 2019). Almost half of the overweight or obese schoolchildren had their SBP changed from normal to high, and a little over 15% moved from high to normal SBP. Among obese and normal-weight students, 21.2 and 4.2%, respectively, remained with high SBP in both follow-ups (p=0.005).

Regarding DBP (Table 3), more than half of normal-weight and overweight schoolchildren remained within the normal range, and over 40% of obese students had this measurement changed from normal to high. Only 6.1% of obese participants had their DBP changed from high to normal, and almost one-fifth of overweight and obese schoolchildren remained with high DBP in both follow-ups (p=0.010).

Table 2. Changes in the systolic blood pressure of schoolchildren according to sex, ethnicity, weight, waist circumference, and body mass index, Vila Velha (ES), 2017 to 2019 (n=133).

	Always normal n=79		**Normal→High n=23**		**High→Normal n=21**		**Always high n=10**		**p-value***
Sex									
Male	39	58.2% (45.8–69.6)	10	14.9% (8.1–25.9)	12	17.9% (10.3–29.3)	6	9.0% (4.0–18.9)	0.759
Female	40	60.6% (48.1–71.9)	13	19.7% (11.6–31.4)	9	13.6% (7.1–24.5)	4	6.1% (2.2–15.4)	
Ethnicity									
White	22	47.9% (33.4–62.6)	11	23.9% (13.4–38.8)	7	15.2% (7.2–29.3)	6	13.0% (5.8–26.8)	0.099
Non-white	57	65.5% (54.7–74.9)	12	13.8% (7.9–22.9)	14	16.1% (9.7–25.6)	4	4.6% (1.7–11.8)	
Weight (kg)†									
Appropriate	67	63.2% (53.5–71.9)	19	17.9% (11.6–26.6)	14	13.2% (7.9–21.2)	6	5.7% (2.5–12.2)	0.151
High	12	46.1% (27.3–66.2)	4	15.4% (5.5–36.2)	6	23.1% (10.1–44.4)	4	15.4% (5.5–36.2)	
WC (cm)									
Appropriate	63	61.8% (51.8–70.8)	17	16.7% (10.5–25.3)	17	16.7% (10.5–25.3)	5	4.8% (2.0–11.4)	0.212
High	16	51.6% (33.6–69.2)	6	19.4% (8.5–38.1)	4	12.9% (4.6–31.1)	5	16.1% (6.5–34.6)	
BMI (kg/m^2)‡									
Normal weight	42	59.1% (47.1–70.2)	10	14.2% (7.6–24.5)	16	22.5% (14.1–34.0)	3	4.2% (1.3–12.6)	
Overweight	22	75.9% (56.0–88.6)	6	20.7% (9.1–40.4)	1	3.4% (0.4–22.9)	-	-	0.005
Obesity	15	45.6% (28.8–63.2)	7	21.2% (10.0–39.4)	4	12.0% (4.4–29.4)	7	21.2% (10.0–39.4)	

WC: waist circumference; BMI: body mass index. The change in blood pressure category was verified in 2017 and 2019. *chi-square test; †category <3rd percentile (n=1) was excluded; ‡not observed in category <3rd percentile.

Table 3. Changes in the diastolic blood pressure of schoolchildren according to sex, ethnicity, weight, waist circumference, and body mass index, Vila Velha (ES), 2017 to 2019 (n=133).

	Always normal n=72		Normal→High n=38		High→Normal n=15		Always high n=8		p-value*
Sex									
Male	37	55.2% (42.9–66.9)	18	26.9% (17.4–39.0)	10	14.9% (8.1–25.9)	2	3.0% (0.7–11.5)	0.302
Female	35	53.0% (40.7–65.0)	20	30.3% (20.2–42.7)	5	7.6% (3.1–17.3)	6	9.1% (4.0–19.1)	
Ethnicity									
White	22	47.8% (33.4–62.6)	18	39.1% (25.8–54.3)	4	8.7% (3.2–21.6)	2	4.4% (1.0–16.5)	0.292
Non-white	50	57.5% (46.7–67.6)	20	23.0% (15.2–33.2)	11	12.6% (7.1–21.6)	6	6.9% (3.1–14.7)	
Weight (kg)†									
Appropriate	60	56.6% (46.9–65.8)	30	28.3% (20.4–37.7)	11	10.4% (5.8–17.9)	5	4.7% (1.9–11.0)	0.331
High	11	42.3% (24.2–62.8)	8	30.8% (15.4–52.0)	4	15.4% (5.5–36.3)	3	11.5% (3.5–32.1)	
WC (cm)									
Appropriate	58	56.9% (46.9–66.3)	27	26.5% (18.7–36.0)	12	11.7% (6.7–19.7)	5	4.9% (2.0–11.4)	0.505
High	14	45.1% (28.0–63.5)	11	35.5% (20.1–54.5)	3	9.7% (2.9–27.4)	3	9.7% (2.9–27.4)	
BMI (kg/m^2)‡									
Normal weight	39	54.9% (43.0–66.3)	17	24.0% (15.2–35.5)	13	18.3% (10.8–29.3)	2	2.8% (0.7–10.9)	0.010
Overweight	20	69.0% (49.0–83.7)	7	24.1% (11.4–44.0)	-	-	2	6.9% (1.6–25.4)	
Obesity	13	39.4% (23.7–57.6)	14	42.4% (26.2–60.4)	2	6.1% (1.4–22.6)	4	12.1% (4.4–29.4)	

WC: waist circumference; BMI: body mass index. The change in blood pressure category was verified in 2017 and 2019. *chi-square test; †category <3rd percentile (n=1) was excluded; ‡not observed in category <3rdpercentile.

Table 4 presents the effect of the independent variables on SBP and DBP. SBP and DBP values were lower in schoolchildren aged eight to nine years (relative risk — RR 0.62; 95%CI 0.48–0.80; RR 0.62; 95%CI 0.48–0.81) than in six- and seven-year-olds. Prevalence of high SBP was greater among students with high WC (RR 1.51; 95%CI 1.20–1.91), weight (RR 1.37; 95%CI 1.08–1.74), and BMI (RR 1.51; 95%CI 1.21–1.87) compared to those with normal measurements. Prevalence of high DBP was greater in schoolchildren with high WC (RR 1.58; 95%CI 1.25–2.00), weight (RR 1.34; 95%CI 1.05–1.71), and BMI (RR 1.50; 95%CI 1.20–1.88). A concomitant interaction was also found between SBP and DBP, indicating that the increase in one variable influences the rise in the other ($p<0.001$).

Table 4. Analysis of the association of the effect of independent variables with systolic and diastolic blood pressure, Vila Velha (ES), 2017 to 2019 (n=1,116).

		SBP		DBP	
		RR (95%CI)	**p-value**	**RR (95%CI)**	**p-value**
Sex	Male	Reference	0.707	Reference	0.172
	Female	1.04 (0.84–1.29)		1.16 (0.03–1.45)	
Age (years)	6–7	Reference	<0.001	Reference	<0.001
	8–9	0.62 (0.48–0.80)		0.62 (0.48–0.81)	
	10–12	0.76 (0.57–1.01)		0.69 (0.51–0.94)	
Ethnicity*	White	Reference	0.137	Reference	0.678
	Non-white	0.83 (0.65–1.06)		0.95 (0.75–1.21)	
Weight (kg)	Appropriate	Reference	0.009	Reference	0.020
	High	1.37 (1.08–1.74)		1.34 (1.05–1.71)	
WC (cm)	Normal	Reference	<0.001	Reference	<0.001
	High	1.51 (1.20–1.91)		1.58 (1.25–2.00)	
BMI (kg/m^2)	Normal	Reference	<0.001	Reference	0.001
	High	1.51 (1.21–1.87)		1.50 (1.20–1.88)	
BP†	Normal	Reference	<0.001	Reference	<0.001
	High	9.68 (7.62–12.29)		10.53 (8.16–13.58)	

SBP: systolic blood pressure; DBP: diastolic blood pressure; RR: relative risk; WC: waist circumference; BMI: body mass index; BP: blood pressure.

*Variable not included in the 2017 follow-up (n=798); †comparison of SBP with DBP and vice versa.

DISCUSSION

This study showed that high weight, WC, and BMI were associated with increased SBP and DBP, with high WC more strongly associated than BMI. On the other hand, when analyzing the progress of BP over the years, despite the results going in the same direction — that is, showing a strong relationship between WC and the increase in BP —, almost half of the overweight or obese schoolchildren progressed from normal to high SBP and more than half moved from normal to high DBP.

Several studies have investigated the relationship between BP and anthropometric indices in students from different countries.[14,22] Study carried out in Taiwan with 2,334 children aged six to seven years found a prevalence of high BP among boys and girls who were in the 4th WC quartile (38.9 and 26.8%, respectively).[23] In Brazil, 3,417 children with normal BMI were assessed, and the increase in WC was associated with high BP, that is, even when BMI was normal.[24] This finding is in line with the result obtained in the present study, which indicates a positive association between WC and pediatric hypertension.

In contrast, other investigations emphasized the relationship between BMI and high BP.[10,25] The Fels longitudinal study suggests that increased BP levels in adulthood might have their genesis in the development of childhood adiposity, expressed by BMI, since students with higher BMI in childhood developed high BP levels in adulthood, regardless of sex and their BMI when adults.[26] In this regard, the study underlines childhood adiposity as one of the factors related to the development of systemic hypertension (SH) in adulthood.[26] This finding corroborates the results of the present study, as more than half of the students with abnormal BMI (overweight or obesity) and normal SBP progressed to increased BP levels or remained with high BP over the years. However, we emphasize that recent studies indicate a positive association between early puberty and an increase in BMI,[27] as well as an interaction effect of the pubertal stage on the association between cardiometabolic risk and BMI.[28]

Among the mechanisms suggested in the literature to explain the relationship between high BP and WC, the latter is considered a highly sensitive and specific measure for upper body fat, which makes individuals more susceptible to cardiovascular diseases and metabolic syndrome, as central obesity can accurately reflect the extent of visceral fat.[29] Although the increase in WC is a well-established risk factor for metabolic syndrome and cardiovascular diseases in adulthood, studies in children are still scarce.[29]Nonetheless, a study conducted with 12,043 Minneapolis students identified that individuals with metabolic syndrome in childhood had more cardiovascular risk factors in adulthood.[30] Still, further studies are needed to better understand the relationship between WC and increased BP in childhood.

Conversely, the Bogalusa Heart Study — involving 11,478 children and adolescents (aged 5–17 years) — found that the sample's SBP and DBP levels did not increase despite the rise in obesity prevalence, indicating that a population's increase in BMI is not necessarily related to BP changes.[31] In addition to this result, a study of two British cohorts revealed that the mean BP did not increase between two generations born 12 years apart, despite the higher levels of BMI. This finding suggests that improvements in other BP-related risk factors in adulthood, such as smoking, salt intake, and physical activity, or even sample characteristics (such as birth weight and mean height) may have somehow influenced the comparative result between cohorts.[10]

The interaction between SBP and DBP should also be considered. In this study, 76% of students with high SBP also presented high DBP. The American Academy of Pediatrics indicated that the increase in DBP is more related to secondary hypertension, whereas systolic hypertension seems to be more predictive of primary SH.[32] Also, the younger the child, the greater the chance of the condition being secondary hypertension.[32] Renal parenchymal disease, renovascular disease, and obstructive nephropathy are responsible for approximately 60 to 90% of these cases and can affect all age groups (infants, children, and adolescents), although their incidence is higher in younger children and those with higher BP elevations.[33] Endocrine disorders, such as excess mineralocorticoid, corticosteroid, or catecholamine, thyroid diseases, and hypercalcemia associated with hyperparathyroidism, account for approximately 5% of cases.[33]The result found, therefore, indicates the need for a detailed investigation, with clinical history and complete physical examination to differentiate cases of primary and secondary hypertension. The reason is that BP measurement is still not routine in most examinations performed in Brazilian children, and secondary causes may go unnoticed, as indicated by the Brazilian Society of Pediatrics.[34]

This study has some limitations. Among them, we highlight that the students assessed were from a single institution, so the sample may not fully represent the schoolchildren from the municipality or state since the present study did not investigate social determinants, particularly sociodemographic characteristics. Furthermore, BP measurements were not double-checked, and not all students had their data collected more than once at different times. However, even with losses, WC and BMI were strongly associated with hypertension. Lastly, the children's pubertal stage was not analyzed, and this aspect might have positively influenced the anthropometric indices and the result of pediatric hypertension, especially in girls.

Among our strengths, we underline that the present study analyzed an anthropometric measure still little investigated in childhood and adolescence — WC. In order to reduce information bias, we adopted certified and calibrated evaluation instruments, as recommended, ensuring data accuracy and reliability. All field researchers were trained to ensure the validity of anthropometric and pressure measurements.

CONCLUSION

The results suggest that both overweight/obese schoolchildren and those with increased WC had higher BP levels, posing a risk for these individuals to become hypertensive adults and, consequently, contributing to the development of cardiovascular diseases. Thus, we expect that these results encourage the production of population-based studies that analyze more thoroughly the relationship of obesity in childhood and adolescence with BP and reinforce the need for BP monitoring and control measures in children and adolescents. In addition, the inclusion of parallel themes in the school curriculum of childhood education, such as healthy eating, physical activity, and reduced screen time, is another important action for tackling such problems.

CONFLICT OF INTERESTS

Nothing to declare.

AUTHORS' CONTRIBUTION

LSPH: Project administration, Data curation, Writing – original draft, Methodology, Writing – review & editing. KAF: Data curation, Writing – original draft, Methodology. GBL: Data curation, Writing – original draft. FBRV: Investigation, Conceptualization. SCC: Investigation, Conceptualization. WLP: Project administration, Formal analysis, Conceptualization, Writing – review & editing, Software, Supervision, Validation, Visualization.

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