Low cardiorespiratory fitness combined with excess adiposity is associated with elevated diastolic blood pressure in Brazilian children

Baja aptitud cardiorrespiratoria combinada con exceso de adiposidad se asocia con presión arterial diastólica en niños brasileños

Autores

Evanise Alves Bolak [1]
Maiara Cristina Tadiotto [1]
Diogo Homann [1]
Caroline Brand [2]
Marcia R Messaggi Gomes Dias [1]
Beatriz Pereira [3]
Rafaela Rosário [3]
Neiva Leite [1]

[1] Federal University of Paraná (Brazil)
[2] Pontificia Universidad Católica de Valparaíso (Chile)
[3] University of Minho (Portugal)

Corresponding author:
Maiara Cristina Tadiotto
mctadiotto@gmail.com

Received: 13-02-26
Accepted: 12-03-26

How to cite in APA

Alves Bolak, E., Tadiotto, M. C., Homann, D., Brand, C., Messaggi Gomes Dias, M. R., Pereira, B., Rosário, R., & Leite, N. (2026). Low cardiorespiratory fitness combined with excess adiposity is associated with elevated diastolic blood pressure in Brazilian children. *Retos, 78*, 806-819. https://doi.org/10.47197/retos.v78.118798

Abstract

Objective: To describe indicators of physical fitness, general and central adiposity, and blood pressure (BP) in schoolchildren aged 6-10 years in Curitiba (Brazil), comparing according to sex, BP status, adiposity, and physical fitness, and analyzing the combined effect of cardiorespiratory fitness (CRF) and adiposity in relation to BP levels.
Methodology: Cross-sectional study with 167 children aged 6-10 years. Body mass, height, waist circumference (WC), systolic BP (SBP), and diastolic BP (DBP) were measured. Body mass index (BMI), BMI z-score (BMI-z), Tri-ponderal mass index (TMI), waist-to-height ratio (WHtR), and mean BP (MBP) were calculated. Physical fitness was assessed by handgrip strength, horizontal jump, and 20-meter shuttle run test. Adiposity was classified as normal or excessive (BMI, TMI, WC, WHtR). Hypertension was defined as BP values ≥P95 for sex and height. Analysis was performed using t-tests, chi-square tests, kruskal–wallis test and binary logistic regression.
Results: Girls had higher body mass (p=0.038) and SBP (p=0.012) than boys. Frequencies of excess general adiposity (BMI-z=40.1%), central adiposity (WHtR=50.3%), and hypertension (17.4%) showed no differences between sexes. Children with high BP had higher means and frequencies of excessive adiposity (p<0.05) and low CRF (p=0.015). Hypertensive measures were associated with TMI (OR=3.15), WC (OR=2.92), WHtR (OR=2.77), and low CRF (OR=3.20) (p<0.05). Children with low CRF combined with high WC or TMI presented higher DBP and MBP than those with high CRF, regardless of adiposity classification (p<0.01).
Conclusions: Children with high BP and hypertension had more general and central adiposity, and low CRF. The combination of low CRF and high adiposity was associated with higher DBP and MBP. Assessments in schoolchildren are important for identifying health risk factors, providing a basis for comprehensive preventive actions.

Keywords

Childhood; health; hypertension; physical activity; schoolchildren.

Resumen

Objetivo: Descripción de los indicadores de aptitud física, adiposidad general y central, y presión arterial (PA) en escolares de 6-10 años en Curitiba (Brasil), comparándolos según sexo, alteraciones de la PA, adiposidad y aptitud física, y analizando la combinación de aptitud cardiorrespiratoria (ACR) y adiposidad en relación con los niveles de PA.
Metodología: Estudio transversal con 167 niños de entre 6-10 años. Se midieron masa corporal, altura, circunferencia de la cintura (CC), PA sistólica (PAS) y PA diastólica (PAD). Se calcularon el índice de masa corporal (IMC), puntuación z del IMC (IMC-z), índice de masa tri-ponderal (IMT), relación cintura-altura (RCA) y PA media (PAM). La aptitud física se evaluó mediante fuerza de prensión manual, salto horizontal y prueba de carrera de ida y vuelta de 20 metros. La adiposidad se clasificó como normal o excesiva (IMC, IMT, CC, RCA). La hipertensión se definió como valores de PA ≥P95 para el sexo y altura. El análisis se realizó mediante pruebas t, pruebas de chi cuadrado, prueba de kruskal-wallis y regresión logística binaria.
Resultados: Las niñas tenían mayor masa corporal (p=0,038) y PAS (p=0,012) que los niños. No se encontraron diferencias entre los sexos a la frecuencia de adiposidad general excesiva (IMC-z=40,1%), adiposidad central (RCA=50,3%) e hipertensión (17,4%). Los niños con PA alta tenían medias y frecuencias más altas de adiposidad excesiva (p<0,05) y baja ACR (p=0,015). Las medidas de hipertensión se asociaron con IMT (OR=3,15), CC (OR=2,92), RCA (OR=2,77) y baja ACR (OR=3,20) (p<0,05). Los niños con bajo ACR combinado con alto CC o IMT presentaron PAD y PAM más altas que aquellos con ACR alto, independientemente de la clasificación de adiposidad (p<0,01).
Conclusiones: Los niños con PA alta e hipertensión presentaron más adiposidad general y central, así como una baja ACR. La combinación de baja ACR y alta adiposidad se asoció con una PAD y PAM más elevada. Las evaluaciones en escolares son importantes para diagnosticar factores de riesgo para la salud, lo que proporciona una base para acciones preventivas integrales.

Palabras clave

Actividad física; escolares; infancia; hipertensión; salud.

Introduction

Health-related risk factors should be identified and monitored in children and adolescents, especially in the presence of excess body mass (De Simone et al., 2022), with the school environment being the most appropriate place to promote health education initiatives in this population (WHO, 2025). Non-invasive measures enable early analysis of general and central excess adiposity, as well as hypertension in schoolchildren. Thus, epidemiological studies that include anthropometric measurements and blood pressure (BP) in schoolchildren are fundamental for preventive and health surveillance actions in the child and adolescent population (Nimkarn et al., 2023; Falkner et al., 2023). However, early diagnosis of hypertension in schoolchildren is difficult due to the low frequency of BP measurement (De Simone et al., 2022). The approach to hypertension in childhood has recently been updated in Brazil, aligning with international recommendations, reflecting an increasing concern about early cardiovascular risk. Unlike previous protocols, current guidelines emphasize that high BP in children should be interpreted as a marker of systemic health, not just an isolated numerical value (Brandão et al., 2025).

Global trends show an increase in the prevalence of childhood hypertension (WHO, 2025), which has concerned the scientific community, especially due to the strong association between excess body mass and reduced regular physical activity (PA) among children and adolescents (Falkner et al., 2023; De Simone et al., 2022). In adolescents, several studies demonstrate the onset of hypertension associated with excessive adiposity, both general (Rodrigues et al., 2018; Nogueira-de-Almeida et al., 2023) and central (Tozo et al., 2020), associated with the presence of metabolic and systemic inflammatory processes (De Simone et al., 2022; Zhang et al., 2025). The risk of hypertension increases sixfold when associated with central obesity and threefold with general obesity (Tozo et al., 2020), as well as being higher in the presence of a sedentary lifestyle and a family history of hypertension (Pinheiro et al., 2021). Conversely, children who regularly engage in PA and spend less time being sedentary tend to have a better adiposity profile, and even in the presence of excess weight, regular PA has a protective effect on diastolic BP (DBP) (Tozo et al., 2020).

Within this context, overweight and obesity are established as the primary modifiable predictors for hypertension in young populations, who are more likely to have low cardiorespiratory fitness (CRF) (Dykstra et al., 2024). These findings converge with the concerns of the World Health Organization (WHO, 2025) about the pandemic spread of obesity, reinforcing that preventing excess weight in childhood is a crucial strategy for mitigating cardiovascular risk in adulthood (WHO, 2025), which includes regular PA. Physical fitness appears to function as a mediator and protector, directly influencing the relationship between anthropometric indicators and BP levels (Chuang et al., 2023). Recent evidence indicates that better physical fitness is associated with lower waist circumference, playing a key role in reducing cardiovascular risk in children (Vasquez et al., 2025). Similarly, studies in schoolchildren have shown that lower CRF and higher adiposity are associated with elevated BP and a greater cardiometabolic risk (Álvarez et al., 2020).

However, identifying hypertension is challenging in children under 10 years of age, as there has been a significant increase in the prevalence of overweight in this age group in recent years (WHO, 2025a), and the cut-off points for diagnosing hypertension vary during physical growth (De Simone et al., 2022). Thus, few epidemiological studies have investigated BP in children alone, with most pediatric research addressing samples that include children and/or adolescents (Tozo et al., 2020; Yazdi et al., 2020; Pinheiro et al., 2021; Nogueira-de-Almeida et al., 2023). A recent study of Chilean schoolchildren aged 6 to 10 years showed that more than half (58.7%) were overweight, which was associated with increased systolic blood pressure (SBP) and reduced physical fitness (Peña-Jorquera et al., 2026). Studies conducted in Portugal indicated an increase in the prevalence of hypertensive disorders in children, ranging from 8.2% to 19.6% (Rodrigues et al., 2018; Leite et al., 2026). In Brazil, the prevalence of hypertension in children has increased, ranging from 6.7% to 10% (Souza et al., 2021; Quitério et al., 2025), reaching higher percentages among overweight children (Nogueira-de-Almeida et al., 2023).

Thus, in children under 10 years of age, there is a gap related to the identification of hypertensive BP levels, and in the understanding of how excess adiposity and low physical fitness interact in the early stages of cardiovascular risk. Most epidemiological studies have focused on adolescents or mixed samples of children and adolescents, limiting the understanding of these relationships during early childhood. Furthermore, few studies have simultaneously examined multiple indicators of general and central adiposity together with CRF when analyzing BP levels in schoolchildren. Investigating the combined influence of CRF and adiposity may help clarify whether higher levels of physical fitness can attenuate the adverse effects of excess adiposity on BP during childhood. Therefore, the objective of this study was to describe physical fitness indicators, general and central adiposity, and BP in schoolchildren aged 6 to 10 years in Curitiba (Brazil), comparing according to sex, BP status, adiposity, and physical fitness, and to analyze the combined influence of CRF and adiposity on BP levels.

Method

Design study

Cross-sectional study conducted between October and December 2025. The protocol was approved by the Research Ethics Committee of the Health Sciences Sector of the Federal University of Paraná (CAEE: 86186424.1.0000.0102) and by the Research Ethics Committee of the Municipal Health Secretariat and the Municipal Education Secretariat (CAEE: 86186424. 1.3001.0101) and authorized by the Municipal Secretariat of Education of Curitiba (Brazil) (protocol no.: 01-130662/2025). Informed consent was obtained from the parents and/or legal guardians of the participating children, as well as informed assent from the schoolchildren themselves, in accordance with the criteria of the Brazilian National Council of Ethics in Research (CNS resolution no. 466/2012).

Participants

The study involved 167 children enrolled in full-time education in the Curitiba Municipal Education system. Schoolchildren were recruited according to the following inclusion criteria: (a) aged between six and 10 years; (b) enrolled in full-time education; (c) no contraindications for performing CRF, muscle strength, and flexibility tests; (d) participating in school physical education (approximately 100 min/week); (e) not taking medications that interfere with the interpretation of research results, such as drugs for BP or weight control. The exclusion criteria were: (a) not participating in all assessments; (b) presence of heart, lung, and osteoarticular diseases that cause clear health impairments.

Procedure

Anthropometric variables

Standardized techniques for measuring height and body mass were followed according to criteria established in the literature. Height was measured with a stadiometer with a resolution of 0.1 cm, and body mass was measured with a digital scale. Body mass index (BMI ($kg \cdot m^{-2}$)) was calculated to classify normal weight and excess weight, and BMI z-score (BMI-z) was used to classify normal weight and excess weight (Onis et al., 2007). Tri-ponderal mass index (TMI ($kg \cdot m^{-3}$)) was used to classify as normal weight and excess weight (Niu et al., 2023). Waist circumference (WC) was measured using a flexible, inextensible tape measure with a resolution of 0.1 cm, and used to classify as normal weight and excess weight (Fernández et al., 2017). Waist-to-height ratio (WHtR) was used to classify as normal weight and excess weight (Nambiar et al., 2010).

Blood pressure

To measure BP and rest heart rate (RHR), the schoolchild was positioned comfortably in a seated position for 10 minutes, using a digital sphygmomanometer and a cuff size appropriate for the arm circumference (Omron®, model HBP-1120). Two BP and RHR measurements were taken, and the mean value was used for analysis. Mean BP (MBP) was estimated by considering one-third of SBP added to two-thirds of DBP. BP was considered high when values were ≥ 90th percentile and < 95th percentile for sex, age, and height, and values ≥ 95th percentile for sex, age, and height were considered hypertension (Brandão et al., 2025).

Physical fitness

Muscle strength was assessed by evaluating upper and lower limb performance. Upper limb strength was assessed using a handgrip strength test with a hydraulic hand dynamometer (Saehan®, model SH5001). The test was performed with the subject standing, positioned with the shoulder adducted, the elbow flexed at 90°, and the forearm in a neutral position. Finally, the wrist position could vary from 0 to 30° extension. The dynamometer was set to zero prior to testing. The highest value (kg) obtained in the three attempts was adopted. The final value of upper limb muscle strength was obtained as the mean of both hands.

The horizontal jump test was used to assess lower limb strength. The child stood behind a marked line, with feet parallel, slightly apart, semi-flexed knees, and torso slightly bent forward. At the evaluator's signal, the subject was instructed to jump as far as possible, bending knees and hips, and landing with both feet simultaneously. The test was performed twice, and the best result was considered for evaluation purposes (cm).

The CRF was measured using the 20-meter shuttle run test (SR-20m). The initial speed of the test was 8.5 km/h, increasing by 0.5 km/h at the end of each one-minute stage. The final score was recorded as the last stage fully completed. The equation by Menezes-Junior et al. (2020) was used to estimate peak oxygen consumption (VO_{2peak}). Participants were classified as having low or normal/high CRF according to age- and sex-specific cut-off points proposed by Sagat et al. (2023).

Data analysis

In the statistical analysis, continuous variables were represented as means ± standard deviation (SD), while categorical variables were presented as absolute values and percentages (%). Normality was assessed using the Shapiro-Wilk test, and diagnostic analysis of standardized residuals via Q–Q plot did not suggest substantial deviations from normality. To verify differences between groups, Student's t-test for independent samples was used. The chi-square test was used for comparisons of categorical variables. To verify differences between groups, a one-way analysis of variance was performed, followed by Bonferroni post hoc tests for multiple comparisons. To verify the association with hypertensive measures, binary logistic regression was performed to determine the odds ratio (OR) and the respective confidence intervals (95% CI). Additionally, the kruskal–wallis test was applied to compare the CRF and adiposity classification groups (high CRF x low CRF x high WC/TMI x low WC/TMI) considering SBP, DBP, and MBP as dependent variables, followed by pairwise comparisons with Bonferroni adjustment. Statistical significance was defined as $p<0.05$. All analyses were performed using SPSS version 29.0.

Results

A total of 167 children (45.5% boys) aged 6-10 years (mean age 8.49 ± 0.93 years) participated in the study. Table 1 shows the descriptive characteristics of the schoolchildren stratified by sex. No differences were observed between boys and girls in the anthropometric variables, except for higher body mass in girls ($p = 0.038$). Regarding BP measurements, girls had a higher mean SBP ($p = 0.012$) compared to boys. The frequencies of hypertensive measurements were similar between the sexes.

Table 2 shows the descriptive characteristics of the children according to BP categorization (normal, elevated BP, and hypertension) and the frequencies of health-related risk factors, such as general adiposity (BMI, BMI-z, TMI) and central adiposity (WC, WHtR), as well as physical fitness classification. In comparison, children with elevated BP and hypertension had higher means in all variables of general and central adiposity ($p < 0.05$), as well as higher means of DBP ($p = 0.025$), but did not differ in SBP and MBP compared to children with normal BP. Regarding physical fitness, lower mean CRF values were observed ($p = 0.015$), but there were no differences in the mean values of upper and lower limb strength.

Regarding proportions, there was a higher frequency of excessive general adiposity according to TMI ($p = 0.007$) and central adiposity by WC ($p = 0.030$) and WHtR ($p = 0.012$) in children with elevated BP and hypertension compared to those with normal BP. Children with elevated BP and hypertension had higher proportions of low CRF ($p = 0.015$) compared to children with normal BP. The proportion of adequate upper limb strength was similar among children with normal BP, elevated BP, and hypertension, but those with elevated BP had a higher proportion of low lower limb strength than those with normal BP and hypertension ($p = 0.034$).

Table 1. Descriptive characteristics of the schoolchildren stratified by sex

Variables	Overall (n=167)	Boys (n=76)	Girls (n=91)	P value
Age (years)	8.49 ± 0.93	8.42 ± 0.95	8.54 ± 0.92	.900
Height (cm)	134.0 ± 8.6	133.8 ± 8.7	134.2 ± 8.5	.712
Body mass (kg)	32.8 ± 8.7	31.7 ± 7.5	33.8 ± 9.5	.038
Body mass index ($kg \cdot m^{-2}$)	18.1 ± 3.3	17.6 ± 3.0	18.5 ± 3.5	.161
Body mass index z-score	0.85 ± 1.3	0.76 ± 1.3	0.93 ± 1.3	.756
Tri-ponderal mass index ($kg \cdot m^{-3}$)	13.5 ± 2.3	13.2 ± 2.1	13.7 ± 2.4	.529
Waist circumference (cm)	61.7 ± 7.9	61.5 ± 7.1	61.9 ± 8.6	.116
Waist-to-height ratio	0.46 ± 0.05	0.46 ± 0.04	0.46 ± 0.05	.219
Upper body strength (kg)	11.6 ± 2.8	11.4 ± 2.7	11.7 ± 2.8	.805
Lower body strength (cm)	120.4 ± 21.3	124.5 ± 21.7	117.0 ± 20.4	.441
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	52.8 ± 7.8	56.3 ± 7.6	50.0 ± 6.8	.233
Systolic blood pressure (mm Hg)	103.7 ± 12.3	103.1 ± 11.1	104.1 ± 13.3	.012
Diastolic blood pressure (mm Hg)	63.9 ± 9.6	62.4 ± 9.7	65.2 ± 9.4	.388
Mean blood pressure (mm Hg)	77.2 ± 9.4	76.0 ± 8.9	78.2 ± 9.8	.601
Rest heart rate (bpm)	85.7 ± 12.5	84.3 ± 13.1	86.9 ± 11.9	.182
Body adiposity				
Body mass index ($kg \cdot m^{-2}$)				
– Normal weight	113 (67.7%)	54 (71.1%)	59 (64.8%)	.392
– Excess weight	54 (32.2%)	22 (28.9%)	32 (35.2%)	
Body mass index z-score				
– Normal weight	100 (59.9%)	49 (64.5%)	51 (56.0%)	.268
– Excess weight	67 (40.1%)	27(35.5%)	40 (44.0%)	
Tri-ponderal mass index ($kg \cdot m^{-3}$)				
– Normal weight	128 (76.6%)	60 (78.9%)	68 (74.7%)	.521
– Excess weight	39 (23.4%)	16 (21.1%)	23 (25.3%)	
Waist circumference (cm)				
– Normal weight	138 (82.6%)	62 (81.6%)	76 (83.5%)	.742
– Excess weight	29 (17.4%)	14 (18.4%)	15 (16.5%)	
Waist-to-height ratio				
– Normal weight	83 (49.7%)	40 (52.6%)	43 (47.3%)	.489
– Excess weight	84 (50.3%)	36 (47.4%)	48 (52.7%)	
Physical fitness				
Upper body strength				
– Low	19 (11.4%)	11 (14.5%)	8 (8.8%)	.096
– Normal/High	148 (88.6%)	65 (85.5%)	83 (91.2%)	
Lower body strength				
– Low	55(32.9%)	20 (26.3%)	35 (38.5%)	.249
– Normal/High	112 (67.1%)	56 (73.7%)	56 (61.5%)	
VO_{2peak}				
– Low	30 (17.9%)	13 (17.1%)	17 (18.7%)	.792
– Normal/High	137 (82.1%)	63 (82.9%)	74 (81.3%)	
Blood pressure				
Stage				
– Normal	115 (68.9%)	59 (77.6%)	56 (61.5%)	.079
– Elevated BP	23 (13.8%)	7 (9.2%)	16 (17.6%)	
– Hypertension	29 (17.4%)	10 (13.2%)	19 (20.9%)	

The category "hypertension" refers to diastolic blood pressure alone or combined with systolic blood pressure, including stage 1 hypertension and combined stage 2 hypertension. Bold = p-values with a significant level of p<0.05

Table 2. Descriptive characteristics of the children and prevalence of health risks factors and physical fitness condition

Variables	Normal BP (n=115)	Elevated BP (n=23)	Hypertension (n=29)	P value
Age (years)	8.6 ± 0.9	8.1 ± 0.9	8.2 ± 0.8	.069
Height (cm)	134.2 ± 8.8	133.2 ± 9.7	133.9 ± 7.1	.892
Body mass (kg)	31.8 ± 6.8	36.0 ± 13.8	34.4 ± 9.6	.057
Body mass index (kg/m^2)	17.5± 2.5	19.7± 4.9	18.9 ± 3.9	.003
Body mass index z-score	0.66 ± 1.1	1.46 ± 1.5	1.12 ± 1.6	.014
Tri-ponderal mass index (kg/m^3)	13.7 ± 1.8	14.7 ± 3.0	14.1 ± 2.6	.001
Waist circumference (cm)	60.6 ± 6.4	65.2 ± 12.4	62.9 ± 8.2	.026
Waist-to-height ratio	0.45 ± 0.0	0.48 ± 0.0	0.47 ± 0.0	.004
Upper body strength (kg)	11.5 ± 2.7	11.9 ± 2.9	11.4 ± 2.6	.798
Lower body strength (cm)	121.4 ± 21.2	114.8 ± 23.9	120.9 ± 19.0	.402
VO_{2peak} ($mL \cdot kg^{-1} \cdot min^{-1}$)	53.8 ± 7.3	48.8 ± 7.9	52.1 ± 8.6	.015
Systolic blood pressure (mm Hg)	103.8 ± 12.0	102.3 ± 13.6	104.3 ± 13.0	.827
Diastolic blood pressure (mm Hg)	62.6 ± 8.4	67.4 ± 10.5	66.5 ± 12.2	.025
Mean blood pressure (mm Hg)	76.3 ± 8.5	79.0 ± 10.4	79.1 ± 11.7	.224
Rest heart rate (bpm)	86.5 ± 12.4	81.0 ± 12.4	86.2 ± 12.8	.152
Body adiposity				
Body mass index ($kg \cdot m^2$)				
Normal weight	84 (73.0%)	13 (56.5%)	16 (55.2%)	.087
Excess weight	31 (27.0%)	10 (43.5%)	13 (44.8%)	
Body mass index z-score				
Normal weight	73 (63.5%)	11 (47.8%)	16 (55.2%)	.320

Excess weight	42 (36.5%)	12 (52.2%)	13 (44.8%)	
Tri-ponderal mass index (kg·m^3)				
Normal weight	96 (83.5%)	15 (65.2%)	17 (58.6%)	.007
Excess weight	19 (16.5%)	8 (34.8%)	12 (41.4%)	
Waist circumference (cm)				
Normal weight	101 (87.8%)	16 (69.6%)	21 (72.4%)	.030
Excess weight	14 (12.2%)	7 (30.4%)	8 (27.6%)	
Waist-to-height ratio				
Normal weight	84 (73.0%)	7 (30.4%)	10 (34.5%)	.012
Excess weight	31 (27.0%)	16 (69.6%)	19 (65.5%)	
Physical fitness				
Upper body strength				
Low	15 (13.0%)	1 (4.3%)	3 (10.3%)	.478
Normal/High	100 (87.0%)	22 (95.7%)	26 (89.7%)	
Lower body strength				
Low	33 (28.7%)	13 (56.5%)	9 (31.0%)	.034
Normal/High	82 (71.3%)	10 (43.5%)	20 (69.0%)	
VO_{2peak}				
Low	14 (12.2%)	7 (30.4%)	9 (31.0%)	.015
Normal/High	101 (87.8%)	16 (69.6%)	20 (69.0%)	

The category "hypertension" refers to diastolic blood pressure alone or combined with systolic blood pressure, including stage 1 hypertension and combined stage 2 hypertension. Bold = p-values with a significant level of p<0.05.

Table 3 shows the association with the risk of hypertensive measurements (odds ratios – OR). A significant association was observed between hypertensive measurements (elevated BP and hypertension) and indicators of general and central adiposity. The risk of hypertensive measurements was twice as high in girls (OR = 2.16; 95% CI: 1.09–4.30; p = 0.027), as well as with high BMI (OR = 2.14; 95% CI: 1.08–4.26; p = 0.029), high WC (OR = 2.92; 95% CI: 1.28–6.64; p = 0.010), and excess weight according to WHtR (OR = 2.77; 95% CI: 1.39–5.51; p = 0.004). This risk was higher when analyzed by TMI (OR = 3.15; 95% CI: 1.50–6.64; p = 0.002). Regarding physical fitness, low VO_{2peak} was associated with a three-fold higher risk of hypertensive measurements (OR = 3.20; 95% CI: 1.42–7.22; p = 0.005).

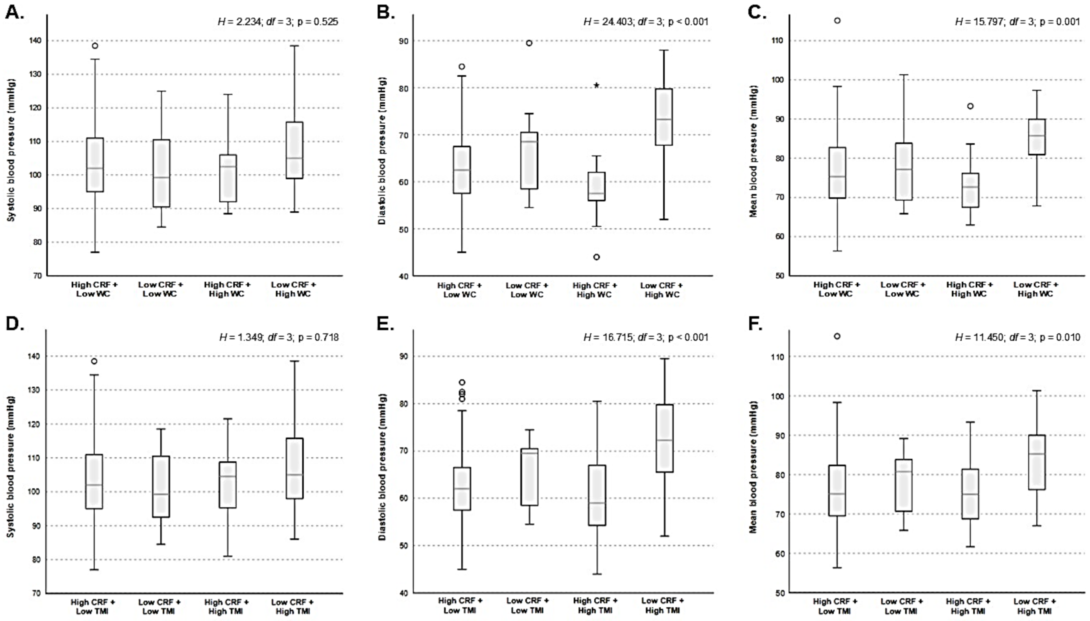
Table 3. Odds ratios for the risk of hypertensive measurements

	Hypertensive Risk		
	Odds ratio	CI95%	P-value
Sex (female)	2.16	1.09 to 4.30	.027
Body mass index (general excess adiposity)	2.14	1.08 to 4.26	.029
Body mass index score z (general excess adiposity)	1.60	0.82 to 3.12	.160
Tri-ponderal mass index (general excess adiposity)	3.15	1.50 to 6.64	.002
Waist circumference (excess central adiposity)	2.92	1.28 to 6.64	.010
Waist-to-height ratio (excess central adiposity)	2.77	1.39 to 5.51	.004
Upper body strength (low)	1.80	0.56 to 5.71	.319
Lower body strength (low)	1.82	0.92 to 3.60	.085
VO_{2peak} (low)	3.20	1.42 to 7.22	.005

VO_{2peak} = peak oxygen consumption; bold = p-values with a significant level of p<0.05.

Multiple comparisons analysis was performed between the groups formed by the combination of CRF (high CRF; low CRF) and WC (high WC; low WC - Figure 1.A-C) and TMI (high TMI; low TMI - Figure 1.D-F) for SBP (Figure 1.A; 1.D), DBP (Figure 1.B; 1.E) and MAP (Figure 1.C; 1.F).

Figure 1. Differences in blood pressure according to cardiorespiratory fitness levels combined with adiposity central and general



Note: Systolic, diastolic, and mean blood pressure according to groups of cardiorespiratory fitness (CRF) and adiposity. A–C: combinations of CRF and waist circumference (WC). D–F: combinations of CRF and tri-ponderal mass index (TMI). Data are presented in boxplots (median, interquartile range, and extreme values). H and p values refer to the Kruskal–Wallis test.

After Bonferroni adjustment, a significant difference was observed for DBP between the High CRF + High WC and the Low CRF + High WC ($Z = -4.300$; $p < 0.001$), as well as between the High CRF + Low WC and the Low CRF + High WC ($Z = -3.999$; $p < 0.001$). These results indicate that schoolchildren with low CRF and high WC presented significantly higher DBP values compared with those with high CRF, regardless of WC classification. Similarly, significant differences were observed for MBP between the High CRF + High WC and the Low CRF + High WC ($Z = -3.556$; $p = 0.002$), as well as between the High CRF + Low WC and the Low CRF + High WC ($Z = -3.575$; $p = 0.002$), indicating higher MBP values among schoolchildren with low CRF and high WC, regardless of WC classification.

For TMI classification, significant differences in DBP were observed between the High CRF + High TMI and the Low CRF + High TMI ($Z = -3.269$; $p = 0.006$), as well as between the High CRF + Low TMI and the Low CRF + High TMI ($Z = -3.730$; $p = 0.001$). Likewise, significant differences were observed for MBP between the High CRF + High TMI and the Low CRF + High TMI ($Z = -2.718$; $p = 0.039$), as well as between the High CRF + Low TMI and the Low CRF + High TMI ($Z = -3.205$; $p = 0.008$). These findings indicate that schoolchildren with low CRF and high TMI presented significantly higher DBP and MBP values compared with those with high CRF, regardless of TMI classification.

Discussion

This study identified the presence of health risk factors in a sample of schoolchildren aged six to 10, with an emphasis on BP status, anthropometric indicators of adiposity (general and central), and low physical fitness. Our results are concerning, as, regardless of sex, almost one-fifth of the sample had hypertension, while one-third had excess general adiposity, and the frequency of excessive central adiposity adjusted for height (WHtR) reached half of the sample. This finding reinforces the urgency of the preventive measures recommended by the Brazilian Guidelines for Hypertension (Brandão et al., 2025). These data not only corroborate the prevalence rates recently observed in Chile (Peña-Jorquera et al., 2026) and Portugal (Rodrigues et al., 2018) but also position overweight and low CRF as the main modifiable challenges for reducing the risk of hypertension in children and adolescents (Pinheiro et al., 2021).

Regarding sex, girls had higher mean body mass and SBP, as well as a higher risk of hypertensive measurements than boys, but the frequency of hypertensive measurements was similar between the sexes. These results reinforce those found in children and adolescents, whose prevalence of hypertension was higher in Iranian girls than in boys (Yazdi et al., 2020), as well as in Portuguese girls (Rodrigues et al., 2018). A recent study in Portuguese schoolchildren (Leite et al., 2026) found higher DBP and RHR in girls than boys, no differences in the proportions of hypertension between the sexes. Peña-Jorquera et al. (2026) identified higher mean SBP in boys but also found no differences in the frequency of hypertensive measurements between the sexes. These differences in BP means may be explained by the characteristics of the samples in each study and the lifestyle of boys and girls. In our study, girls had a higher body mass and a higher risk of hypertensive measurements than boys, while in the Chilean study, no anthropometric differences were found between the sexes, but girls had a higher proportion of adequate WHtR and upper limb strength (Peña-Jorquera et al., 2026).

An important aspect of this study was the observation of the risk of general and central overweight in relation to hypertensive measurements in children, which was observed across all anthropometric indicators. The risk of hypertension was twice as high in children with high BMI, WC, and WHtR. Notably, this risk increased threefold when analyzed by TMI. Our results are consistent with studies that indicated TMI as a more significant anthropometric marker for discriminating body fat distribution than BMI and show a stronger relationship with high BP in children and adolescents (Kuciene et al., 2023). Increased central adiposity, assessed by WC and WHtR, presents a higher risk of hypertension and greater prognostic value for predicting changes in BP in adolescents (Tozo et al., 2020). However, research in Iranian children and adolescents reports that anthropometric measures of central (WC) or general adiposity (BMI) have similar but weak predictive power to identify risk factors for increased BP (Yazdi et al., 2020).

Results from Rodrigues et al. (2018) in Portuguese children under 10 years of age revealed that the risk of high BP associated with general adiposity was six times higher in boys and four times higher in girls, while central adiposity tripled the risk in boys and doubled it in girls. It is noteworthy that girls were more likely to be classified with hypertensive BP levels, with a fivefold increase in the presence of general adiposity and a twofold increase for central adiposity, results that were not significant in boys (Rodrigues et al., 2018). Quitério et al. (2025) observed that excess BMI increased the risk of diastolic hypertension by almost three times in girls with high BP, when compared to girls with normal BMI and to boys, but without significance in the risk of hypertension for high TMI and WC. Another aspect was age group. Pereira et al. (2020) observed that while general obesity doubles the risk of high BP in children aged six to seven years, this probability quadruples in the eight to nine-year-old age group, reinforcing the progressive impact of adiposity on the pediatric hemodynamic profile. Other results in Portuguese girls revealed higher risks of hypertension associated with maternal overweight and lack of PA outside school (Rodrigues et al., 2018).

Regarding physical fitness, the present study did not show differences between the sexes, both in terms of means and in the proportions of adequate and low frequencies in the physical fitness variables. Our data corroborate the American study by Gahche et al. (2017), which also found no differences in CRF between boys and girls aged six to nine years. Most of our sample had satisfactory levels of physical fitness, with less than one-fifth of children showing reduced VO_{2peak} values, both boys and girls, even with adiposity levels reaching almost half of our sample. It is interesting to note that our results differ from those found in the Chilean study, in which two-thirds of children had low CRF and approximately half had reduced upper and lower limb muscle strength, especially boys. Similarly, Chilean children with overweight had higher mean SBP, hypertension proportions, and inadequate CRF than children with normal weight (Peña-Jorquera et al., 2026). These findings are consistent with those of Dykstra et al. (2024) and Nascimento et al. (2023), who associate obesity with a higher probability of low CRF.

In the present study, children classified with elevated BP and hypertension had higher proportions of low CRF, reaching almost one-third of these subgroups. This finding reinforces the evidence from Dong et al. (2020) showing the inverse association between physical fitness and hypertension. In a systematic review conducted by Mintjens et al. (2018), about half of the articles reported inverse associations between ACR (in childhood and adolescence) and BMI, higher adiposity, and metabolic syndrome in the future. However, they presented controversies regarding the evidence for other cardiovascular risk factors. According to the authors, many studies did not consider the control of confounding variables, such as adiposity. It should be emphasized that, in the study by Gahche et al. (2017), children with overweight and obesity had a higher prevalence of low physical fitness compared to children with normal weight.

Our findings regarding the combined influence of CRF and adiposity on BP are consistent with previous research conducted in Latin-American schoolchildren. Álvarez et al. (2020) observed that lower levels of CRF were associated with higher adiposity indicators and increased SBP, DBP, and MBP in schoolchildren from Colombia, Brazil, and Chile. Moreover, the authors showed that the phenotype characterized by high CRF combined with low adiposity presented the lowest BP levels, whereas the combination of low CRF and high adiposity resulted in the highest cardiovascular risk profile. These findings reinforce the hypothesis that the interaction between fitness and fatness plays a crucial role in the early development of cardiometabolic risk in children.

Furthermore, in our study, more than half of the children with high BP had low lower limb strength, which represented a higher proportion than normal BP and hypertensive children, but there were no differences in the proportion of adequate upper limb strength between the three groups. Regarding lower limb muscle strength, our results converge with the study by Chuang et al. (2023), which pointed out that lower performance in the long jump was a factor associated with pediatric hypertension independently of BMI percentile. Thus, explosive lower limb strength appears to influence BP levels, as well as low CRF. Similarly, overweight Chilean children had higher proportions of low lower limb strength and WHtR but had a higher proportion of adequate upper limb strength than children with normal weight (Peña-Jorquera et al., 2026).

The differences in muscle strength, adiposity, and BP levels may be related to the fact that, in the prepubertal age group, muscle performance is primarily mediated by neuromuscular adaptations. Wilmore et al. (2020) explain that in children at this stage, strength gains occur without significant hypertrophy, given the low concentration of testosterone. Unlike adolescents and adults, in whom strength is closely related to muscle mass and hormone levels, strength in young children depends on the efficiency of motor unit recruitment and intramuscular coordination (Malina et al., 2009). These factors appear to remain preserved, even in the early stages of BP changes.

In our study, low lower limb muscle strength was not associated with the risk of hypertensive measurements in children, while low CRF was a critical factor, increasing the probability of this outcome fourfold. These data corroborate the findings of Diaz et al. (2021), which indicate that high levels of CRF are associated with a lower probability of hypertension, especially in children with excessive adiposity, suggesting that improving CRF can mitigate metabolic risks regardless of body weight. In addition, Lukhele et al. (2024) reinforces that children with normal weight tend to have higher levels of CRF and, consequently, a lower risk of developing obesity and hypertension at an early age. These results are partially supported by a systematic review on the subject, which found that high levels of CRF in childhood and adolescence were associated with lower general (BMI) and central (WC) adiposity, as well as a lower prevalence of metabolic syndrome in adulthood. However, the authors did not observe associations between CRF in the pediatric phase and future BP measurements, lipid profile, and glucose homeostasis, suggesting the importance of standardizing CRF in objective measures such as VO_{2max} (Mintjens et al., 2018).

Although muscle strength may be preserved during childhood, low CRF and being overweight are warning signs for future cardiometabolic health impairment. In this sense, CRF has been highlighted as a key modulator for cardiovascular risk trajectories, in which high levels of fitness in childhood can neutralize the development of cardiovascular diseases, not only in the pediatric phase but also in adulthood (Hauser et al., 2023).

Therefore, structured exercise and extracurricular PA programs that simultaneously address obesity and high BP are essential to promote significant improvements in children's public health (Zhou et al., 2025; Pano et al., 2025). The prevention of childhood obesity is no longer purely a nutritional goal but has become a central strategy in mitigating early cardiovascular risk. It is noteworthy that in the study with Portuguese schoolchildren, girls showed lower participation in moderate-to-vigorous PA and higher participation in light PA during weekdays and on weekends compared to boys (Leite et al., 2026), a factor that may have contributed to higher DBP and increased risk of elevated BP in girls, but no differences in the frequency of hypertension were observed. Moderate-to-vigorous PA is inversely associated with the risk of increased BP (Pinheiro et al., 2021). Therefore, differences in physical fitness and lifestyle may be decisive in the mean BP of boys and girls, but in this age group, they may not yet represent an increase in the frequency of hypertension.

It should be emphasized that insufficient levels of PA and sedentary behavior are directly related to increased adiposity and worsening cardiometabolic health (Moraes-Junior et al., 2025). In the present study, the risk related to general and central overweight and BP was evident, converging with findings from other national and international investigations. Pereira et al. (2020) observed that this risk was present, as well as that overweight significantly increased the probability of hypertension in Brazilian children aged six to 10 years. This trend is corroborated by other studies (Quitério et al., 2025; Peña-Jorquera et al., 2026), which also identified overweight and obesity as determining predictors for the development of high BP levels in this age group.

This study has some limitations. BP was measured during a single assessment session, although two measurements were performed. According to clinical guidelines, the diagnosis of hypertension in children should be confirmed by repeated measurements obtained on different occasions. Therefore, these results should be interpreted with caution. Furthermore, it did not consider the multifactorial determinants of childhood hypertension, including as both non-modifiable and modifiable factors. Among the non-modifiable factors, we highlight genetic predisposition, family history, and prenatal conditions, such as exposure to tobacco, gestational diabetes, and low birth weight (Falkner et al., 2023). Regarding modifiable factors, lifestyle plays a central role, with hypertension being aggravated by high sodium intake, physical inactivity, and diets lacking in vegetables (Pileggi et al., 2021), factors not addressed in this study. In addition, socioeconomic and environmental determinants, such as low parental education and passive smoking, are directly associated with the prevalence of the disease (Annisa et al., 2024). Thus, the inclusion of additional variables and further investigation of the causal mechanisms of hypertension in this population should be addressed in future studies. Such investigations will be essential to refine early intervention strategies and clinical monitoring of children aged six to 10 years.

The positive aspect of this study was the screening of schoolchildren, including BP measurements, which enables risk profiling and the development of health promotion strategies for early BP management (Chuang et al., 2023). Hypertension in childhood should be addressed and lifestyle changes encouraged, with an emphasis on regular PA (De Simone et al., 2022). The literature reiterates the importance of CRF as a marker of health in childhood, as moderate levels of CRF act as protective factors that optimize growth and biopsychosocial development during late childhood (Nascimento et al., 2023). It should be noted that the assessment of CRF in the school environment should not be seen only as a momentary measure, but as an essential tool for the continuous monitoring of child public health (Nascimento et al., 2023). Thus, there is a need for policies that encourage active play over sedentary behaviors, with a view to maintaining adequate levels of physical fitness, especially CRF, which emerges as an indispensable strategy for the prevention of hypertension.

Conclusions

Children with excess general and central adiposity had a higher proportion of elevated BP, with the risk of hypertension being significantly increased by BMI and WC. Children with hypertensive BP levels had less favorable physical fitness, although upper limb muscle strength was preserved in this age group. However, the frequencies of low lower limb strength and low CRF were higher and proved to be important risk factors for both elevated BP and hypertension. Furthermore, the combined analysis of CRF and adiposity showed that children with low CRF and high adiposity presented higher DBP and MBP levels. We found a higher risk of hypertension in girls aged six to 10 years, a factor that should be evaluated in future studies, especially in relation to PA during weekdays and weekends. Periodic assessments in the school environment are important for the early identification of overweight, hypertension, and low physical fitness in children. The identification of risk factors in childhood can inform comprehensive preventive actions and the planning of strategies to improve future health.

Acknowledgements

The authors would like to thank research group Núcleo de Qualidade de Vida at the Federal University of Paraná (Brazil), the IRyS Group at the Pontificia Universidad Católica de Valparaíso (Chile), the Centro de Investigação em Estudo da Criança (CIEC) at the University of Minho (Portugal), the School of Nursing at the University of Minho (Portugal), and the Health Sciences Research Unit: Nursing (UICISA: E) at the Nursing School of Coimbra (Portugal) for their valuable institutional and scientific support. The authors sincerely thank the participating schools, children, and their families for their collaboration in this study.

Financing

This study was supported by the Brazilian International Project 402698/2024-0 – CNPq (Conselho Nacional de Desenvolvimento Científico e Tecnológico) Call for Proposals 16/2024, which enabled the meeting and interaction between researchers from Brazilian, Chilean, and Portuguese universities. This work was financially supported by Portuguese national funds through the FCT (Foundation for Science and Technology) within the framework of the CIEC (Research Centre on Child Studies of the University of Minho) project under the reference UID/00317/2025. MCT received support from the CNPq Scholarship. NL received support from a CNPq Scholarship.

References

Álvarez, C., Cadore, E., Gaya, A. R., Mello, J. B., Reuter, C. P., Delgado-Floody, P., Ramos-Sepúlveda, J. A., Carrillo, H. A., Devia, D. G., & Ramírez-Vélez, R. (2022). Associations of cardiorespiratory fitness and obesity parameters with blood pressure: fitness and fatness in youth Latin-American ethnic minority. Ethnicity & Health, 27(5), 1058–1074. https://doi.org/10.1080/13557858.2020.1840525

Annisa, N., Haryanto, J.; & Kristiawati, K. (2024). Exploring the risk factors associated with hypertension in children: A systematic review. Pediomaternal Nursing Journal,10(1), 33-38. https://doi.org/10.20473/pmnj.v10i1.54528

Brandão, A. A., Rodrigues, C. I. S., Bortolotto, L. A., Armstrong, A. D. C., Mulinari, R. A., Feitosa, A. D. M., ... Nadruz, W. (2025). Brazilian Guidelines of Hypertension - 2025. Arquivos Brasileiros de Cardiologia, 122(9), e20250624. https://doi.org/10.36660/abc.20250624

Bento de Moraes Junior, F., Cristina Tadiotto, M. ., Ribeiro Paes Corazza, P. ., Jose de Menezes-Junior, F. ., Brand, C. ., Mota, J. ., & Leite, N. (2025). Social isolation during the covid-19 pandemic impaired vitamin d concentrations, motor performance and physical fitness in adolescents. *Retos*, *62*, 715-724. https://doi.org/10.47197/retos.v62.109217

Chuang, H. H., Cherng, W. J., Lin, C. H., Lee, L. A., Hsu, K. H., & Lin, R. H. (2023). Physical fitness mediates and predicts for high blood pressure among children in relation to weight status. Frontiers in Public Health, 11, 1157351. https://doi.org/10.3389/fpubh.2023.1157351

de Simone, G., Mancusi, C., Hanssen, H., Genovesi, S., Lurbe, E., Parati, G., Sendzikaite, S., Valerio, G., Di Bonito, P., Di Salvo, G., Ferrini, M., Leeson, P., Moons, P., Weismann, C. G., & Williams, B. (2022). Hypertension in children and adolescents. European Heart Journal, 43(35), 3290–3301. https://doi.org/10.1093/eurheartj/ehac328

Diaz, E. C., Weber, J. L., Adams, S. H., Young, C. G., Bai, S., & Børsheim, E. (2021). Cardiorespiratory fitness associates with blood pressure and metabolic health of children-the Arkansas Active Kids Study. Medicine and Science in Sports and Exercise, 53(11), 2225–2232. https://doi.org/10.1249/MSS.0000000000002701

Dong, Y., Jan, C., Zou, Z., Dong, B., Hu, P., Ma, Y., Yang, Z., Wang, X., Li, Y., Gao, D., Wen, B., Song, Y., & Ma, J. (2020). Comprehensive physical fitness and high blood pressure in children and adolescents: A national cross-sectional survey in China. Journal of Science and Medicine in Sport, 23(9), 800–806. https://doi.org/10.1016/j.jsams.2020.02.016

Dykstra, B. J., Griffith, G. J., Renfrow, M. S., Mahon, A. D., & Harber, M. P. (2024). Cardiorespiratory and muscular fitness in children and adolescents with obesity. Current Cardiology Reports, 26(5), 349–357. https://doi.org/10.1007/s11886-024-02036-3

Falkner, B., Gidding, S. S., Baker-Smith, C. M., Brady, T. M., Flynn, J. T., Malle, L. M., South, A. M., Tran, A. H., Urbina, E. M., & American Heart Association Council on Hypertension; Council on Lifelong Congenital Heart Disease and Heart Health in the Young; Council on Kidney in Cardiovascular Disease; Council on Lifestyle and Cardiometabolic Health; and Council on Cardiovascular and Stroke Nursing (2023). Pediatric primary hypertension: an underrecognized condition: a scientific statement from the American Heart Association. Hypertension, 80(6), e101–e111. https://doi.org/10.1161/HYP.0000000000000228

Fernández, J. R., Bohan Brown, M., López-Alarcón, M., Dawson, J. A., Guo, F., Redden, D. T., & Allison, D. B. (2017). Changes in pediatric waist circumference percentiles despite reported pediatric weight stabilization in the USA. Pediatric Obesity, 12(5), 347–355. https://doi.org/10.1111/ijpo.12150

Gahche, J. J., Kit, B. K., Fulton, J. E., Carroll, D. D., & Rowland, T. (2017). Normative values for cardiorespiratory fitness testing among us children aged 6-11 years. Pediatric Exercise Science, 29(2), 177–185. https://doi.org/10.1123/pes.2016-0167

Hauser, C., Lichtenstein, E., Nebiker, L., Streese, L., Köchli, S., Infanger, D., Faude, O., & Hanssen, H. (2023). Cardiorespiratory fitness and development of childhood cardiovascular risk: The EXAMIN YOUTH follow-up study. Frontiers in Physiology, 14, 1243434. https://doi.org/10.3389/fphys.2023.1243434

Kuciene, R., & Dulskiene, V. (2023). Associations between tri-ponderal mass index, body mass index, and high blood pressure among children and adolescents: a cross-sectional study. Scientific Reports, 13(1), 18148. https://doi.org/10.1038/s41598-023-45432-5

Leite, N., Tadiotto, M. C., Duarte, A., Augusto, C., Silva, M. J., Brand, C., Mota, J., Pereira, B., & Rosário, R. (2026). Sex differences in blood pressure and physical activity among socioeconomically vulnerable Portuguese schoolchildren aged 6 to 10 years: insights from the BeE-school Project. BMC Pediatrics. Advance online publication. https://doi.org/10.1186/s12887-026-06704-x

Lukhele, N. P., Millard, L., & Breukelman, G. J. (2024). Impact of weight status on hemodynamic parameters and aerobic fitness in school-aged children: a study in a rural school community. International Journal of Environmental Research and Public Health, 21(10), 1340. https://doi.org/10.3390/ijerph21101340

Malina, R. M., Bouchard, C., Bar-Or, O. (2009). Crescimento, maturação e atividade física. 2 ed., Porto Alegre: Phorte.

Menezes-Junior, F. J., Jesus, Í. C., Mota, J., Lopes, M. F. A., Corazza, P. R. P., Tadiotto, M. C., Tozo, T. A. A., Purim, K. S. M., Ronque, E. R. V., & Leite, N. (2020). Validation of equations to estimate the peak oxygen uptake in adolescents from 20 metres shuttle run test. Journal of Sports Sciences, 38(22), 2588–2596. https://doi.org/10.1080/02640414.2020.1794255

Mintjens, S., Menting, M. D., Daams, J. G., van Poppel, M. N. M., Roseboom, T. J., & Gemke, R. J. B. J. (2018). Cardiorespiratory fitness in childhood and adolescence affects future cardiovascular risk factors: a systematic review of longitudinal studies. Sports Medicine, 48(11), 2577–2605. https://doi.org/10.1007/s40279-018-0974-5

Nambiar, S., Hughes, I., & Davies, P. S. (2010). Developing waist-to-height ratio cut-offs to define overweight and obesity in children and adolescents. Public Health Nutrition, 13(10), 1566–1574. https://doi.org/10.1017/S1368980009993053

Nascimento, E., Chaves, R., Rodriguez-Añez, C., & Ribas, M. S. (2023). Physical and motor profile of children between 6 and 10 years old according to levels of cardiorespiratory fitness. Revista Brasileira de Cineantropometria & Desempenho Humano, 25, e94396. https://doi.org/10.1590/1980-0037.2023v25e94396

Niu, Y., Zhang, Y., Sheng, J., Lu, W., Li, J., Mao, X., Cai, W., Tang, Q., Shen, X., & Feng, Y. (2023). Tri-ponderal mass index as a screening tool for obesity prediction in children aged 6-9 years. Frontiers in Endocrinology, 14, 1277125. https://doi.org/10.3389/fendo.2023.1277125

Nimkarn, N., Sewarit, A., Pirojsakul, K., Paksi, W., Chantaragh, S., Saisawat, P., & Tangnararatchakit, K. (2023). Waist-to-height ratio is associated with sustained hypertension in children and adolescents with high office blood pressure. Frontiers in Cardiovascular Medicine, 9, 1026606. https://doi.org/10.3389/fcvm.2022.1026606

Nogueira-de-Almeida, M. E., Mello, E. D., Ued, F. V., Del Ciampo, L. A., Ferraz, I. S., Rodrigues, A. C., Silva, R. F. B., & Nogueira-de-Almeida, C. A. (2023). High levels of blood pressure among Brazilian overweight and obese children and adolescents. Medicina, 56(2), e-195377. https://doi.org/10.11606/issn.2176-7262.rmrp.2023.195377

Onis, M., Onyango, A. W., Borghi, E., Siyam, A., Nishida, C., & Siekmann, J. (2007). Development of a WHO growth reference for school-aged children and adolescents. Bulletin of the World Health Organization, 85(9), 660–667. https://doi.org/10.2471/blt.07.043497

Pano, G., Nuriu, D., Petri, O., Lile, A., Muja, E., & Bajaziti, A. (2025). Efectos de la actividad física extraescolar sobre los parámetros cardiovasculares en niños de 11 a 16 años. Retos, 73, 1101-1111. https://doi.org/10.47197/retos.v73.117618

Peña-Jorquera, H., Pavez-San Martin, G., Pérez-Tapia, M., Gálvez-Guzmán, A., Pinheiro, G., Rosário, R., Tadiotto, M. C., Leite, N., & Brand, C. (2025). Presión arterial, composición corporal y condición física en escolares Chilenos. Journal of Movement & Health, 23(1).

Pereira, F. E. F., Teixeira, F. D. C., Kac, G., Soares, E. A., & Ribeiro, B. G. (2020). Overweight and obesity associated with high blood pressure: a cross-sectional study in Brazilian students. Sobrepeso e obesidade associados à pressão arterial elevada: um estudo seccional em escolares brasileiros. Revista da Escola de Enfermagem da U S P, 54, e03654. https://doi.org/10.1590/S1980-220X2019036203654 P

Pileggi, C., Papadopoli, R., De Sarro, C., Nobile, C. G. A., & Pavia, M. (2021). Obesity, blood pressure, and intraocular pressure: a cross-sectional study in Italian children. Obesity Facts, 14(2), 169–177. https://doi.org/10.1159/000514096

Pinheiro, G., Mello, J., Gaya, A., & Gaya, A. R. (2021). Blood pressure in children: association with anthropometric indicators, body composition, cardiorespiratory fitness and physical activity. Arquivos Brasileiros de Cardiologia, 116(5), 950–956. https://doi.org/10.36660/abc.20190520

Quitério, R. J., Bolak, E. A. A., Almeida, M. C. S., Moraes, F. R., Lopes, W. A., Mota, J., Tadiotto, M. C., & Leite, N. (2025). O excesso de adiposidade geral foi associado a maior risco de hipertensão diastólica em crianças. REVISTA DELOS, 18(73), e6948. https://doi.org/10.55905/rdelosv18.n73-040

Rodrigues, P. R. M., Pereira, R. A., Gama, A., Carvalhal, I. M., Nogueira, H., Rosado-Marques, V., & Padez, C. (2018). Body adiposity is associated with risk of high blood pressure in Portuguese schoolchildren. Revista Portuguesa de Cardiologia, 37(4), 285–292. https://doi.org/10.1016/j.repc.2017.09.016

Sagat, P., Štefan, L., Petrić, V., Štemberger, V., & Blažević, I. (2023). Normative values of cardiorespiratory fitness in Croatian children and adolescents. PloS One, 18(4), e0284410. https://doi.org/10.1371/journal.pone.0284410

Souza, B. G. A., Guimarães, L. L. S., Felisbino-Mendes, M. S., Lachtim, S. A. F., Vieira, E. W. R. (2021). Prevalence disparities of hypertension among adolescents in Brazil. Revista da Sociedade Brasileira de Enfermagem Pediátrica, 21(2), 78-84.

Tozo, T. A., Pereira, B. O., Menezes Junior, F. J., Montenegro, C. M., Moreira, C. M. M., & Leite, N. (2020). Hypertensive measures in schoolchildren: risk of central obesity and protective effect of moderate-to-vigorous physical activity. Arquivos Brasileiros de Cardiologia, 115(1), 42–49. https://doi.org/10.36660/abc.20180391

Wilmore, J. H., Costill, D. L., Kenney, W. L. (2020). Fisiologia do Esporte e do Exercício. 7. ed. Barueri: Manole.

World Health Organization. (2025). Global report on hypertension 2025. high stakes - turning evidence into action. Geneva: World Health Organization.

Yazdi, M., Assadi, F., Qorbani, M., Daniali, S. S., Heshmat, R., Esmaeil Motlagh, M., & Kelishadi, R. (2020). Validity of anthropometric indices in predicting high blood pressure risk factors in Iranian children and adolescents: CASPIAN-V study. Journal of Clinical Hypertension, 22(6), 1009–1017. https://doi.org/10.1111/jch.13895

Zhang, W., Wang, Q., Liu, H., Hong, F., Tang, Q., Hu, C., Xu, T., Lu, H., Ye, L., Zhu, Y., & Song, L. (2025). Systemic inflammation markers and the prevalence of hypertension in 8- to 17-year-old children and adolescents: A NHANES cross-sectional study. Nutrition, Metabolism, and Cardiovascular Diseases, 35(2), 103727. https://doi.org/10.1016/j.numecd.2024.08.020

Zhou, J., Sun, W., Tang, S., Jiang, D., Tan, B., Li, S., Zhao, D., Zhang, R., & Song, P. (2025). Effects of exercise interventions on blood pressure in children and adolescents with overweight or obesity: a systematic review and meta-analysis of randomized controlled trials. The Journal of Adolescent Health, 76(3), 361–369. https://doi.org/10.1016/j.jadohealth.2024.09.017

Authors and translators' details:

Evanise Alves Bolak	ebolak@educacao.curitiba.pr.gov.br	Author
Maiara Cristina Tadiotto	mctadiotto@gmail.com	Author
Diogo Homann	diogomann@hotmail.com	Author
Caroline Brand	carolbrand@hotmail.com.br	Author
Marcia Regina Messaggi Gomes Dias	mrmgdias@gmail.com	Author
Beatriz Pereira	beatriz@ie.uminho.pt	Author
Rafaela Rosário	rrosario@ese.uminho.pt	Author
Neiva Leite	neivaleite@gmail.com	Author
Ana Beatriz Costa Bomfim	anabbomfim@gmail.com	Translator