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High blood pressure screening in children and adolescents from Amargosa, Bahia: usefulness of anthropometric indices of obesity

Triagem da pressão arterial elevada em crianças e adolescentes de Amargosa, Bahia: utilidade de indicadores antropométricos de obesidade

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ABSTRACT: ***Objective:*** To determine the predictive power of body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR), and their respective cut-off points for high blood pressure (BP) screening in Brazilian children and adolescents. ***Method:*** Cross-sectional study conducted with 1,139 students aged 6 to 17 years. Body weight, height, WC, and BP were measured. High BP was classified as systolic or diastolic ≥ 95^{th} percentile. Receiver Operating Characteristic (ROC) curves were constructed, and the area under the curve, sensitivity, and specificity were calculated. ***Results:*** The prevalence of high BP was 27.0%. Anthropometric indices showed a significant association with high BP (accuracy ranging from 0.62 – 0.81), except for WHtR among male adolescents. Sensitivity was low, regardless of the anthropometric index, gender, and age group. ***Conclusion:*** BMI, WC, and WHtR were associated with high BP, but the cut-off points tested showed low sensitivity. Determining specific cut-off points for each population can enable the use of anthropometric indices in high BP screening.

Keywords: Arterial pressure. Obesity. Body mass index. Waist circumference. Child.

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RESUMO: ***Objetivo*:** Determinar o poder preditivo do índice de massa corporal (IMC), perímetro da cintura (PC) e razão da cintura pela estatura (RCEst) e de seus respectivos pontos de corte para triagem de pressão arterial (PA) elevada em crianças e adolescentes brasileiros. ***Método*:** Estudo transversal realizado com 1.139 escolares de 6 a 17 anos de idade. A massa corporal, a estatura, o PC e a PA foram mensurados. A PA elevada foi classificada como sistólica ou diastólica ≥ percentil 95. Curvas *Receiver Operating Characteristic* (ROC) foram construídas e a área sob a curva, a sensibilidade e a especificidade foram calculadas. ***Resultados*:** A prevalência de PA elevada foi de 27,0%. Os indicadores antropométricos apresentaram associação significativa com PA elevada (acurácia variando de 0,62 – 0,81), exceto RCEst entre adolescentes do sexo masculino. Observou-se baixa sensibilidade, independentemente do indicador antropométrico, do sexo e da faixa etária. ***Conclusão*:** O IMC, o PC e a RCEst estiveram associados a PA elevada, porém os pontos de corte testados apresentaram baixa sensibilidade. A determinação de pontos de corte específicos para cada população pode viabilizar a triagem de PA elevada por meio de indicadores antropométricos.

Palavras-chave: Pressão arterial. Obesidade. Índice de massa corporal. Circunferência da cintura. Criança.

INTRODUCTION

High blood pressure (BP) is considered the main individual risk factor for disease burden and overall mortality. In 2013, estimates indicated that this condition was responsible for 10.4 million deaths and more than 8% of disability-adjusted years of life lost[1]. Considering the significant prevalence rates of high BP among children and adolescents[2,3] and the increased risk of this condition persisting in adulthood[4], efforts for early diagnosis and intervention are necessary.

After the age of three, young people should have their BP measured in every clinical assessment, at least annually, as part of their pediatric primary care[5]. However, in Brazil, BP monitoring in pediatric age groups is still inadequate and does not cover a large proportion of young people, especially those belonging to the less favored social classes[6]. The reasons for the under-evaluation of BP are little studied, but could be related to the short duration of pediatric appointments, lack of equipment, especially appropriate cuffs for the arm circumference of young people, and the difficulty in interpreting BP values due to their complex classification criterion – based on percentile distribution according to age, gender, and height[7,8].

After recognizing the under-evaluation of BP and the strong association between obesity and high BP in childhood and adolescence[9-11], the use of anthropometric indices such as body mass index (BMI), waist circumference (WC), and waist-to-height ratio (WHtR) can represent a simple, non-invasive, and low-cost strategy in the screening of young people with increased risk of high BP. The school routine could include the anthropometric assessment, and young people at risk of developing high BP could be referred to family health units for a more detailed clinical evaluation.

Several studies have investigated the power of BMI, WC, and WHtR in predicting high BP in young people, but it is still not clear which of these anthropometric indices would be more suitable for high BP screening[9,10,12-15]. In addition, the definition of the BMI, WC, and WHtR classification criterion with better sensitivity and specificity in detecting high BP among young Brazilians remains open, as previous investigations tested few cut-off points of these indices[10,12,15]. These gaps are even more evident in children given that a large part of national studies included only adolescents in their sample[10,12,15]. Thus, the objective of this study was to:

1. determine the predictive power of BMI, WC, and WHtR for high BP in Brazilian children and adolescents;
2. test the ability of different BMI, WC, and WHtR cut-off points in identifying young people with and without high BP.

METHOD

The present study is part of a school-based epidemiological survey developed in Amargosa, Bahia, Northeast region of Brazil, considered a small city, with an estimated population of 34,845 inhabitants in 2012 and human development index (HDI) of 0.625. The study population consisted of public and private school students of both genders, aged 6 to 17 years, attending from 1st to 9th grade of elementary school and from 1st to 3rd grade of high school.

We used an estimated prevalence of 50% (for various outcomes), a confidence level of 95%, and a maximum allowable error of three percentage points to calculate the sample size. The sample size estimated was 971 children and adolescents. We added 20% (n = 194) for possible cases of incomplete data or refusals to participate in data collection. After the loss of 2.2%, the sample analyzed (n = 1,139) had 90% power (β = 10%) and confidence level of 95% (α = 5%) to detect areas under the Receiver Operating Characteristic (ROC) curve equal to or greater than 0.58 as significant.

The sample selection process had two stages, with "school" being the primary sampling unit and "student," the secondary. The first stage used a cluster sample of schools proportionally stratified by type of school ("urban public," "rural public," and "private"). Five urban public, five rural public, and one private school were selected, with the estimated sample size for each stratum being proportional to the study population. The second stage selected the students by simple drawing, considering the number of individuals required in each school to compose a sample equivalent to its size. Data were collected from August 2011 to May 2012. All evaluations occurred at school during the morning period. The Research Ethics Committee of Maria Milza College approved the protocol of the present study (process No. 126/2011). The study included only students who voluntarily agreed to participate and whose parents or legal guardian signed the Informed Consent Form authorizing their involvement.

The previously calibrated digital automatic monitor Omron, model HEM-742 INT (Omron Healthcare, Illinois, United States), measured BP levels. Cuffs with an appropriate size to the arm circumference of the children and adolescents assessed were used both to calibrate the monitor and to measure BP levels. The measurement was taken in the right arm at heart level after the student rested for five minutes. High BP was classified as systolic or diastolic ≥ 95th percentile, and adjusted for gender, age, and height[16].

A Plenna (Plenna, São Paulo, Brazil) digital scale, with capacity for 150 kg and resolution of 100 g measured body weight. The scale underwent a calibration test based on the standard weight comparison method with indications of the calibrated instrument, according to the electronic scale procedure, approved following Inmetro Directive No. 236/94[17]. Height was measured using a Seca portable stadiometer, model Bodymeter 208 (Seca Ltd., Birmingham, United Kingdom), fixed to the wall, graduated from 0 to 220 cm, with an accuracy of 0.1 cm. Both variables were measured following standardized procedures and techniques[18] and used to calculate BMI [BMI = body weight (kg)/height^2 (m)]. BMI was classified according to four criteria: International Obesity Task Force (IOTF)[19], World Health Organization (WHO)[20], Centers for Disease Control and Prevention (CDC)[21], and Conde and Monteiro[22]. We distributed the students into the groups "normal weight" or "excess weight" (overweight and obesity). WC was measured with an inelastic anthropometric tape (Cescorf, Brazil) with a resolution of 0.1 cm, based on procedures described by WHO[23], and classified as normal or high according to criteria proposed by Taylor et al.[24], Katzmarzyk et al.[25], Fernández et al.[26], and CDC[27]. Due to the lack of consensus over which percentile to use to define abdominal obesity in young people, we adopted both the 75 (75th) percentile and the 90 (90th) percentile of the criteria by Fernández et al.[26] and CDC[27], respectively, to classify high WC in the studied sample. We calculated WHtR using height and WC measures. High WHtR was defined according to a cut-off point designed for adults (≥ 0.5)[28] and the specific cut-off points for children and adolescents suggested by Kelishadi et al.[9] and Zhou et al.[29].

The descriptive data analysis used mean, median, standard deviation, percentiles, and frequency. The Mann-Whitney test verified the differences between genders (male versus female) and age groups (children = 6 – 9 years versus adolescents = 10 – 17 years) for systolic and diastolic BP, BMI, WC, and WHtR ($p < 0.05$). The predictive power of BMI, WC, and WHtR for high BP was estimated with ROC curves for each gender in two age groups (children = 6 – 9 years and adolescents = 10 – 17 years). We adopted a confidence interval (CI) of 95%, considering significant areas under the ROC curve whose CI lower limits were ≥ 0.50. The difference in accuracy between anthropometric indices associated with high BP was calculated according to Hanley and McNeil[30]. We estimated the sensitivity and specificity of different BMI, WC, and WHtR classification criteria using high BP as an outcome. The software SPSS (version 20.0) and MedCalc (version 9.1.0.1) analyzed the data.

RESULTS

The mean age of the sample was 11.51 years (standard deviation = 3.33). The prevalence of high BP was 27.0% (95%CI 24.5 – 29.6) [male = 24.8% (95%CI 21.2 – 28.6); female = 28.8% (95%CI 25.4 – 32.4); children = 9.4% (95%CI 6.8 – 12.8); adolescents = 35.2% (95%CI 31.9 – 38.6)]. Table 1 shows the differences for BP and anthropometric indices according to gender and age group. Female individuals and adolescents had significantly higher medians for systolic and diastolic BP, BMI, and WC ($p < 0.05$). WHtR presented higher medians among females and children ($p < 0.05$).

Anthropometric indices showed a significant association with high BP, except for WHtR among male adolescents (Table 2). For male children, BMI and WC accuracy was significantly greater than WHtR ($p = 0.001$ and $p = 0.002$, respectively) (Table 2). For females, the three anthropometric indices investigated had similar accuracy ($p > 0.05$) in both children and adolescents (Table 2).

Obesity prevalence presented a substantial variation with the use of different classification criteria, particularly for WC and WHtR (Table 3). In general, the BMI cut-off points proposed by WHO[20] and Conde and Monteiro[22] showed a better balance between sensitivity and specificity in identifying young people with and without high BP. However, regardless of the criterion used to classify BMI, sensitivity was low, especially among adolescents (Table 3). The WC and WHtR cut-off points suggested by Katzmarzyk et al.[25] and Kelishadi et al.[9], respectively, showed a better

Table 1. Systolic and diastolic blood pressure and anthropometric indices according to gender and age group. Amargosa, Bahia, 2011–2012.

	n	Systolic BP[a] (mmHg)	Diastolic BP[a] (mmHg)	BMI[a] (kg/m^2)	WC[a] (cm)	WHtR[a]
Gender						
Male	506	114 (104; 122)	65 (60; 71)	17 (16; 19)	63 (56; 70)	0.44 (0.42; 0.46)
Female	633	115 (106; 124)	68 (62; 74)	18 (16; 21)	67 (59; 73)	0.46 (0.43; 0.49)
p-value[b]		0.048	0.001	0.001	0.001	0.001
Age group (years)						
Children (6 – 9)	363	106 (99; 115)	62 (57; 67)	16 (15; 17)	56 (53; 60)	0.45 (0.43; 0.48)
Adolescents (10 – 17)	776	117 (109; 126)	69 (63; 74)	19 (17; 21)	69 (63; 75)	0.45 (0.42; 0.48)
p-value[b]		0.001	0.001	0.001	0.001	0.041
Total	1,139	114 (105; 123)	66 (61; 73)	17 (16; 20)	65 (58; 72)	0.45 (0.42; 0.48)

BP: blood pressure; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; [a]median (25; 75 percentiles); [b]Mann-Whitney test.

balance between sensitivity and specificity in identifying young people with and without high BP, except for WHtR among male adolescents, whose cut-off points were not tested (Table 3).

DISCUSSION

The anthropometric indices investigated showed a significant association with high BP, except for WHtR among male adolescents. Nevertheless, testing the cut-off points available in the literature revealed that sensitivity was low, no matter the anthropometric index, gender, and age group used. To increase the chances of early diagnosis and treatment, the applicability of anthropometric indices in the screening of children and adolescents with high BP should prioritize methods with high sensitivity values, consequently, minimizing the number of false-negative results[31].

The prevalence of high BP found in the present study was superior to that described for the Brazilian[3] and North-American[32] pediatric populations. Data from the Bogalusa Heart Study published in 1995 already showed that high BP levels in childhood persist over time and tend to progress to hypertension in adult life[4]. Among the young people investigated, 93.3% reported excessive consumption of cold cuts, salted meat, and offal (data not shown). According to information previously published on the sample under study, approximately two-thirds of young people were insufficiently active, increasing by 32% their chances of having high BP; also, those with elevated values for obesity indices were more likely to

Table 2. Accuracy of anthropometric indices in predicting high blood pressure according to gender and age group. Amargosa, Bahia, 2011–2012.

Anthropometric indices	Male	Female
	AUC (95%CI)	AUC (95%CI)
Children		
BMI	0.81 (0.74 – 0.87)[a,b]	0.78 (0.71 – 0.83)[a]
WC	0.78 (0.71 – 0.84)[a,b]	0.71 (0.64 – 0.77)[a]
WHtR	0.62 (0.54 – 0.69)[a,b,c]	0.74 (0.67 – 0.80)[a]
Adolescents		
BMI	0.67 (0.62 – 0.72)[a]	0.63 (0.59 – 0.68)[a]
WC	0.65 (0.60 – 0.70)[a]	0.63 (0.58 – 0.68)[a]
WHtR	0.51 (0.46 – 0.57)	0.62 (0.57 – 0.63)[a]

AUC: area under the ROC curve; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; 95%CI: confidence interval of 95%; [a]area under the ROC curve indicating discriminatory power for high BP (confidence interval lower limit ≥ 0.50); [b]significant difference in the area under the curve between BMI and WHtR ($p < 0.05$); [c]significant difference in the area under the curve between WC and WHtR ($p < 0.05$).

Table 3. Prevalence of estimated obesity for different classification criteria of anthropometric indices and sensitivity and specificity values for high blood pressure screening according to gender and age group. Amargosa, Bahia, 2011–2012.

Anthropometric indices	Male			Female		
	Obesity prevalence (%)	SE (%)	SP (%)	Obesity prevalence (%)	SE (%)	SP (%)
Children						
BMI						
IOTF[19]	13.5	42.9	89.2	19.3	45.0	83.6
WHO[20]	18.1	42.9	84.1	23.4	55.0	80.1
CDC[21]	16.4	42.9	86.0	18.8	45.0	84.2
Conde and Monteiro[22]	14.6	42.9	87.9	25.0	55.0	78.4
WC						
Taylor et al.[24]	11.2	35.7	91.0	20.3	50.0	83.0
Katzmarzyk et al.[25]	38.0	57.1	63.7	49.0	65.0	52.6
CDC (75th)[27]	8.2	8.3	92.9	14.1	20.0	92.9
CDC (90th)[27]	1.2	3.1	100.0	4.2	10.0	96.5
Fernández et al. (75th)[26]	14.0	21.4	81.5	20.8	25.0	83.6
Fernández et al. (90th)[26]	4.7	7.1	95.5	8.3	25.0	93.6
WHtR						
0.5[28]	14.1	35.7	87.8	24.0	55.0	79.5
Kelishadi et al.[9]	38.2	50.0	62.8	49.5	70.0	52.6
Zhou et al.[29]	27.6	35.7	73.1	62.0	90.0	40.9
Adolescents						
BMI						
IOTF[19]	13.1	18.0	89.2	17.5	24.7	86.7
WHO[20]	16.7	23.4	86.5	20.6	27.2	83.2
CDC[21]	13.7	18.0	88.3	16.6	23.5	87.5
Conde and Monteiro[22]	17.0	24.3	86.5	21.8	30.2	83.2
WC						
Taylor et al.[24]	14.0	22.5	90.1	25.9	37.0	80.3
Katzmarzyk et al.[25]	37.6	45.0	65.9	55.3	64.2	49.8
CDC (75th)[27]	6.3	11.7	92.4	8.6	9.3	91.0

Continue...

Table 3. Continuation.

Anthropometric indices	Male			Female		
	Obesity prevalence (%)	SE (%)	SP (%)	Obesity prevalence (%)	SE (%)	SP (%)
CDC (90th)[27]	0.9	0.9	99.1	2.3	4.3	98.9
Fernández et al. (75th)[26]	15.2	22.5	85.7	20.0	19.7	84.0
Fernández et al. (90th)[26]	5.4	9.0	96.4	6.6	13.6	97.5
WHtR						
0.5[28]	-	-	-	25.0	34.6	80.6
Kelishadi et al.[9]	-	-	-	61.4	69.1	43.2
Zhou et al.[29]	-	-	-	60.9	67.9	43.2

IOTF: International Obesity Task Force; WHO: World Health Organization; CDC: Centers for Disease Control and Prevention; BMI: body mass index; WC: waist circumference; WHtR: waist-to-height ratio; SE: sensibility; SP: specificity; Note: cut-off points were not tested in cells indicated with "-", as the area under the ROC curve for the variable was not significant enough to predict high blood pressure in male adolescents.

have high BP[33]. Another aspect to consider is the fact that the population in the Northeast region still presents worrying indicators of education, occupation, income, housing, sanitation, and access to public health services[34]. These factors are determinant of cardiovascular outcomes[35] and can explain, at least in part, the significant prevalence of high BP in the sample investigated.

Among the anthropometric indices assessed, BMI showed the highest accuracy values to predict high BP, despite being only significantly greater than WHtR among male children. Our findings corroborate previous studies that indicate BMI as a better predictor of high BP compared to other anthropometric indices of cardiovascular risk[36,37]. Evidence suggests that obese young people have more chances (between 1.5 and 5 times greater) of developing high BP than non-obese ones[10,12,13]. Also, in a longitudinal study conducted with 7,203 Chinese children (aged six to eight years), BMI significantly affected the incidence of hypertension[38]. In addition to its wide use by the scientific community and clinical practice, body weight and height, and consequently BMI, are usually measured in pediatric appointments, Basic Family Health Units, and schools, which can facilitate the high BP screening in childhood and adolescence[36].

Comparatively, the BMI cut-off points proposed by WHO[20] and Conde and Monteiro[22] showed a better balance between sensitivity and specificity in identifying young people with and without high BP. However, regardless of the criterion used to classify BMI, sensitivity was low. Moraes et al.[15] tested the BMI cut-off points proposed by IOTF[19], CDC[21], and Conde and Monteiro[22] to predict high BP in 817 young people aged 6 to 13 years. As in the present study, sensitivity showed low values (31 to 44%), no matter the criterion used, with the Brazilian one being the most sensitive.

WC has been considered one of the main predictors of abdominal fat[24] and has a positive correlation with BP in Brazilian children and adolescents[11]. Our study revealed a moderate association between WC and high BP – area under the ROC curve (AUC) ranging from 0.63 to 0.78. However, after testing the cut-off points existing in the literature, we found a wide variation in obesity prevalence and, usually, low sensitivity. As observed in the present investigation, previous studies that compared the ability of WC cut-off points developed with samples of young North-Americans also showed low sensitivity in screening cardiovascular risk factors among the Brazilian pediatric population[10,12,39]. In our study, the cut-off points suggested by Katzmarzyk et al.[25], although less than satisfactory, showed a better balance between sensitivity and specificity in identifying young people with and without high BP in both genders and age groups. Also, the cut-off points based on percentile distribution (CDC[27] and Fernández et al.[26]) had the worse ability in identifying young people with high BP, which was more evident when testing the 90 percentile. The scarcity of studies with national samples that compared referenced cut-off points for cardiovascular risk factors (for instance, Katzmarzyk et al.[25]) with referenced cut-off points for percentile distribution (for example, CDC[27] and Fernández et al.[26]) complicates assessments and prevents the definition of a more accurate classification criterion to detect high BP in young Brazilians.

Out of the three anthropometric indices tested, WHtR showed the worst performance in identifying young people with high BP. In addition to the lack of association with male adolescents, its accuracy was statistically lower than BMI and WC among male children. The ability of WHtR in screening cardiovascular risk factors in young adults is controversial. While some authors suggest that WHtR is the best index of cardiometabolic risk factors for the pediatric population[14,40], others advocate that height does not provide any additional advantage to WC, as well as, not improving the accuracy of BMI when added to this index[13,37]. Our findings demonstrated that the cut-off points for this index suggested by Kelishadi et al.[9] presented a better balance between sensitivity and specificity in identifying young people with and without high BP in both genders and age groups. The 0.5 cut-off point developed for adults[28] — and commonly used to classify WHtR in young people[13,14] — showed the worst ability in detecting high BP. Motswagole et al.[41] reported lower sensitivity values for the WHtR 0.5 cut-off point compared to the 0.41 cut-off point for high BP screening in young people and suggested that adopting a value < 0.5 could improve the use of WHtR as a marker of high BP in the pediatric population.

The use of merely statistical critical values for anthropometric indices in the context of screening for risk factors in children and adolescents seems to produce a high number of false-negative results and, consequently, tends to underestimate the prevalence of the disease[42]. With respect to the screening for BP changes in the pediatric population, the greater concern is defining cut-off points for anthropometric indices that allow the identification of a larger number of young people with high BP, given that adopting fewer sensitive criteria contributes to delaying the early implementation of measures targeted at the control of BP levels. In addition, cut-off points from high-income countries do not seem to be the most suitable to use in middle- and low-income ones[42]. Previous studies that tested cut-off points developed based on their samples showed high values for both sensitivity and specificity[15,39,42]. Thus, we can reasonably affirm that the success of screening for cardiovascular risk factors in children and adolescents using anthropometric indices might be related to the development and use of specific cut-off points for each population.

The main strength of this study was assessing the ability of different BMI, WC, and WHtR cut-off points in screening high BP in a school-based probabilistic sample consisting of Brazilian children and adolescents of both genders. However, our study has limitations such as measuring BP on a single occasion, which might have overestimated its high prevalence. At least three visits on different days are recommended to diagnose hypertension, since BP values can fluctuate, especially among children and adolescents due to their excitability for activities that are not part of their routine, such as BP measurement. For this reason, the present study focused on abnormal BP values, using the term "high BP" instead of hypertension. Also, taking measurements in two or more different occasions is operationally complicated in population studies[3]. Another limitation was using a cross-sectional design in our study, which did not allow us to establish a causal relationship between anthropometric indices and BP. Regarding the external validity of the study, we underline that, as shown in a previous study[33], the present research was conducted with a sample of children and adolescents from the Northeast region of Brazil, with predominance of monthly household income below the minimum wage, maternal schooling inferior to eight years of study, and social classes C, D, and E. The specific socioeconomic and demographic profile of the young people studied does not allow the extrapolation of our findings to populations from other countries or even other regions of Brazil with distinct characteristics to those investigated here.

CONCLUSION

Despite the association between anthropometric indices and the outcome analyzed, the cut-off points found in the literature were unsatisfactory for high BP screening in the sample investigated. Developing an epidemiological survey with national representation to determine specific cut-off points could enable the use of anthropometric indices in high BP screening in Brazilian children and adolescents. Despite the number of cut-off points available in the literature at the moment, public policies that stimulate and enable the use of BMI and WC as part of monitoring the growth and development of the pediatric population in schools and family health units should be encouraged. We emphasize that the routine clinical evaluation of children and adolescents should include measuring their BP, regardless of their current weight.

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