J Pediatr (Rio J). 2020;96(2):168–176

sociedade brasileira de pediatria

Jornal de Pediatria

www.jped.com.br

ORIGINAL ARTICLE

Blood pressure reference values for Brazilian adolescents: data from the Study of Cardiovascular Risk in Adolescents (ERICA Study)☆

Thiago Veiga Jardim[a,b,*], Bernard Rosner[c], Katia Vergetti Bloch[d], Maria Cristina Caetano Kuschnir[e], Moyses Szklo[f,g], Paulo César Veiga Jardim[a]

[a] *Universidade Federal de Goiás, Liga de Hipertensão Arterial, Goiânia, GO, Brazil*
[b] *Brigham & Women's Hospital, Division of Cardiovascular Medicine, Boston, United States*
[c] *Channing Laboratory, Department of Biostatistics, Harvard T.H. Chan School of Public Health, Boston, United States*
[d] *Universidade Federal do Rio de Janeiro, Instituto de Estudos em Saúde Coletiva, Rio de Janeiro, RJ, Brazil*
[e] *Universidade do Estado do Rio de Janeiro, Faculdade de Ciências Médicas, Rio de Janeiro, RJ, Brazil*
[f] *The Johns Hopkins University, Department of Epidemiology, Baltimore, United States*
[g] *The Johns Hopkins University, Department of Medicine (Cardiology), Baltimore, United States*

Received 17 May 2018; accepted 4 September 2018
Available online 4 December 2018

KEYWORDS
Pediatric;
Office blood pressure;
Hypertension;
Blood pressure measurement/monitoring;
Diagnostic method

Abstract

Objective: Blood pressure (BP) references for Brazilian adolescents are lacking in the literature. This study aims to investigate the normal range of office BP in a healthy, non-overweight Brazilian population of adolescents.

Method: The Brazilian Study of Cardiovascular Risks in Adolescents (Portuguese acronym ''ERICA'') is a national school-based study that included adolescents (aged 12 through 17 years), enrolled in public and private schools, in cities with over 100,000 inhabitants, from all five Brazilian macro-regions. Adolescents' height and body mass index (BMI) were classified in percentiles according to age and gender, and reference curves from the World Health Organization were adopted. Three consecutive office BP measurements were taken with a validated oscillometric device using the appropriate cuff size. The mean values of the last two readings were used for analysis. Polynomial regression models relating BP, age, and height were applied.

Results: Among 73,999 adolescents, non-overweight individuals represented 74.5% (95% CI: 73.3–75.6) of the total, with similar distribution across ages. The majority of the non-overweight sample was from public schools 84.2% (95% CI: 79.9–87.7) and sedentary 54.8% (95%

☆ Please cite this article as: Jardim TV, Rosner B, Bloch KV, Kuschnir MC, Szklo M, Jardim PC. Blood pressure reference values for Brazilian adolescents: data from the Study of Cardiovascular Risk in Adolescents (ERICA Study). J Pediatr (Rio J). 2020;96:168–76.

* Corresponding author.
E-mails: tdesouzaveigajardim@bwh.harvard.edu, thiagoloirin@hotmail.com (T.V. Jardim).

https://doi.org/10.1016/j.jped.2018.09.003
0021-7557/© 2018 Sociedade Brasileira de Pediatria. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

CI: 53.7–55.8). Adolescents reporting their skin color as brown (48.8% [95% CI: 47.4–50.1]) or white (37.8% [95% CI: 36.1–39.5]) were most frequently represented. BP increased by both age and height percentile. Systolic BP growth patterns were more marked in males when compared to females, along all height percentiles. The same pattern was not observed for diastolic BP.
Conclusions: Blood pressure references by sex, age, and height percentiles for Brazilian adolescents are provided.
© 2018 Sociedade Brasileira de Pediatria. Published by Elsevier Editora Ltda. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

PALAVRAS-CHAVE
Pediátrico;
Pressão arterial no consultório;
Hipertensão;
Mensuração/monitorização da pressão arterial;
Método diagnóstico

Valores de referência para pressão arterial em adolescentes brasileiros: dados do Estudo dos Riscos Cardiovasculares em Adolescentes (Estudo ERICA)

Resumo
Objetivo: Referências de pressão arterial (PA) para adolescentes brasileiros estão ausentes na literatura. Este estudo tem como objetivo investigar a variação normal da pressão arterial no consultório em uma população brasileira saudável de adolescentes sem sobrepeso.
Método: O Estudo dos Riscos Cardiovasculares em Adolescentes (ERICA) é um estudo brasileiro, de âmbito nacional e de base escolar, que incluiu adolescentes (12 a 17 anos) matriculados em escolas públicas e privadas, em cidades com mais de 100.000 habitantes, de todas as cinco macrorregiões brasileiras. A altura e o índice de massa corporal (IMC) dos adolescentes foram classificados em percentis de acordo com a idade e o sexo, sendo adotadas as curvas de referência da Organização Mundial de Saúde. Foram realizadas três medidas consecutivas de PA no consultório com um dispositivo oscilométrico validado, utilizando o manguito de tamanho apropriado. Os valores médios das duas últimas leituras foram utilizados nas análises. Modelos de regressão polinomial relacionando PA, idade e estatura foram aplicados.
Resultados: Entre os 73.999 adolescentes, os indivíduos sem sobrepeso representaram 74,5% (IC95%: 73,3-75,6) do total, com distribuição similar entre as idades. A maior parte da amostra sem sobrepeso originava-se das escolas públicas, com 84,2% (IC95%: 79,9-87,7), e os sedentários 54,8% (IC95%: 53,7-55,8). Os adolescentes que relataram sua cor de pele como parda (48,8% [IC95%: 47,4-50,1]) e branca (37,8%: [IC 95% 36,1-39,5]) foram os mais representados. A PA aumentou tanto com a idade, quanto com o percentil de altura. Os padrões de aumento sistólico da PA foram mais acentuados no sexo masculino quando comparados ao sexo feminino, em todos os percentis de altura. O mesmo padrão não foi observado para a PA diastólica.
Conclusões: São fornecidas referências de pressão arterial por sexo, idade e percentil de altura para adolescentes brasileiros.
© 2018 Sociedade Brasileira de Pediatria. Publicado por Elsevier Editora Ltda. Este é um artigo Open Access sob uma licença CC BY-NC-ND (http://creativecommons.org/licenses/by-nc-nd/4.0/).

Introduction

Elevated blood pressure (BP) in children and adolescents is a public health concern worldwide,[1] and it is mainly attributable to a remarkable increase in childhood obesity over the past three decades.[2] The rate of hypertension (HTN) diagnosis in this age group is estimated to have doubled in the past two decades.[3] HTN in the pediatric population is associated with target organ damage[4] and moderately tracks into high BP in adulthood.[5]

Measuring BP during physical examination in pediatric clinical practice was quite unusual until a few years ago.[6] Nowadays, the importance of BP measurement in children and adolescents is unquestionable, and the remaining issue is whether to use auscultatory or oscillometric devices.[7] The available reference values for defining blood pressure (BP) classes, recommended in most guidelines,[7–9] were defined by the auscultatory method. Notwithstanding, the ease of use, the minimization of observer bias or digit preference (which are the common errors associated with the auscultatory method),[10] and the recent banning of mercury devices in the European Community will undoubtedly favor the use of oscillometric devices.[11] From that perspective, it is convenient to start assembling reference BP data for using oscillometric devices[11] in children and adolescents.

Unlike the adult population, there is no childhood hypertension definition based on clinically defined, health-risk-related cut-off levels for increased BP. Instead, age-specific, sex-specific, height-specific, and population-based distributions of BP (90th and 95th percentiles) are used to define normal BP thresholds.[12] BP percentiles should not be provided as a function of weight, because relatively high BP would be considered normal merely because a child is overweight.[13] The increasing obesity prevalence could result in inappropriate norms for BP if overweight children are included in the normative database.[12]

Despite the global growing use of oscillometric devices in adolescents, to the authors' knowledge, there are no available studies assessing pediatric BP references for healthy normal-weight Brazilian adolescents based on oscillometric measurements. Furthermore, no references at all, using any kind of BP measurement devices, are available for Brazilian adolescents.

The present study aims to provide age-, height-, and sex-stratified systolic and diastolic BP reference values in non-overweight Brazilian adolescents using a validated oscillometric device. Further, the study aims to compare the obtained normative values with available international BP percentiles from auscultatory[1,13] and oscillometric[12,14] devices.

Methods

This study is part of the Study of Cardiovascular Risk in Adolescents (Portuguese acronym ''ERICA''), which is a national, cross-sectional, school-based study, aimed at estimating the prevalence of metabolic syndrome and other cardiovascular risk factors in adolescents aged between 12 and 17 years.

The sample was divided into 32 strata, comprised of 27 capitals of Brazilian States and five cities with more than 100,000 inhabitants from each of the five geographic regions of the country. Stratification was done according to three categories: schools, year/shift class combinations, and classrooms. Thus, the sample was representative at the national and regional, levels, and also at the level of State capitals.

Sample size calculation was based on an expected metabolic syndrome prevalence of 4%,[15] a maximum estimation error of 0.9%, a confidence level of 95%, and a design effect of 2.97. The sampling process has been fully described previously.[16]

ERICA was approved by the Research Ethics Committee (REC) of each participating institution. Adolescents' were included in the study after signing a consent form and, when required by local the REC, after having an informed consent form signed by their legal guardian.

Information about sex, age, type of school (public or private), skin color, smoking, alcohol consumption, and physical activity were obtained from a self-administered questionnaire using a personal digital assistant (PDA) for data entry.

Adolescents were grouped into six age groups: ≥12 and <13 years; ≥13 and <14 years; ≥14 and <15 years; ≥15 and <16 years; ≥16 and <17 years; ≥17 and <18 years. Skin color included five categories: white, black, brown, yellow, and indigenous, according to the Brazilian Institute of Geography and Statistics classification.[17] Adolescents who reported smoking on one or more days in the past 30 days were considered smokers, following the Centers for Disease Control and Prevention[18] and the Brazilian National Cancer Institute's recommendations.[19] Alcohol consumption was defined as a positive answer to the question whether the adolescents consumed alcohol (at least one glass or a dose) within the past 30 days.[20]

Physical activity level was assessed by the Self-Administered Physical Activity Checklist, which has been previously validated for the Brazilian population.[21] The level was determined by the sum of the product of the time spent in each physical activity and the respective frequency. Adolescents who spent less than 300 min per week in moderate to vigorous physical activity were considered inactive.[22]

Height was measured using a calibrated portable stadiometer (Alturexata, Minas Gerais, Brazil) with millimeter resolution and height up to 213 cm. Individuals were in full standing position and measurements were taken in duplicate for quality control purposes (if the difference exceeded 0.5 cm, height needed to be measured again). Mean value of the two measures was used in the analysis. Height percentiles were classified according to the World Health Organization (WHO) curves.[23]

Body weight was measured using an electronic scale (Líder, Model P200M, São Paulo, Brazil), with 300 kg of capacity and 50 g precision.

Waist circumference (WC) was measured using an inelastic measuring tape, with 0.1 cm resolution and length of 1.5 m (Sanny, São Paulo, Brazil). Individuals were at upright position, with abdomen relaxed at the end of gentle expiration. Measurements were performed horizontally at half distance between the iliac crest and the lower costal margin, and were taken in duplicate for quality control purposes (if the difference exceeded 1 cm, WC had to be measured again). The mean value of the two measures was used in the analysis.

Arm length was measured from the acromion to the olecranon using the same measuring tape used for WC measurements. The midpoint on the dorsal (back) surface of the arm was marked with a pen. The participant was asked to relax the arm alongside the body and the measuring tape was placed snugly around the arm at the midpoint mark, keeping the tape horizontal. The tape should not indent the skin.

Nutritional status was classified according to body mass index (BMI), namely the body mass (kg) divided by the square of the body height (m). Reference curves from the WHO were adopted,[23] using the BMI-for-age chart, according to sex. The following cut-off points were adopted: Z-score <-3 (very low weight); Z-score ≥ -3 and <-2 (low weight); Z-score ≥ -2 and ≤ 1 (normal weight); Z-score > 1 and ≤ 2 (overweight); Z-score > 2 (obesity).

Blood pressure

Blood pressure measurements were performed following the recommendations of the 4th Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents, published in 2004.[24] The oscillometric device Omron® 705-IT (Omron Healthcare, Bannockburn, USA), previously validated for use in adolescents,[25] was used. The appropriate cuff size for the upper right arm was indicated according to arm length measurements.[24] Three consecutive BP measures were taken for each individual, with an interval of three minutes between each. The mean values of 2nd and 3rd readings were used in this analysis in order to reduce the impact of reactivity on the blood pressure (higher first reading).[26]

Statistical analyses

Statistical analyses took into account the complex sampling that considers all variability sources of the ERICA sample.[16] The sampling weight was calculated by the products of the inverse of the probabilities of inclusion in each selection stage, and calibrated by age and sex, considering the estimated number of adolescents enrolled in schools located in the geographic strata included in the study.

Normally distributed variables were expressed as means and 95% confidence intervals (95% CI) and categorical variables as proportions and 95% CI.

For BP percentiles estimations girls were assessed apart from boys. Systolic and diastolic BP were then separately regressed with age (with up to a polynomial of terms: age, age^2, age^3, and age^4) and height *Z*-score (with up to a polynomial of terms: z, z^2, z^3, and z^4):

$$BP = \beta_0 + \beta_1 z + \beta_2 z^2 + \beta_3 z^3 + \beta_4 z^4 + \beta_5 (age - 15) + \beta_6 (age - 15)^2 + \beta_7 (age - 15)^3 + \beta_8 (age - 15)^4 + (\sigma * z_\alpha)$$

where σ denotes the regression residual standard deviation, and $z_\alpha = 0$, $z_\alpha = 1.28155$, $z_\alpha = 1.64485$, $z_\alpha = 2.32635$ for the 50th, 90th, 95th, and 99th percentiles, respectively.

Regression residual standard deviation was obtained by estimating a residual for each observation followed by calculating a weighted residuals sum of squares, where the applied weight was the survey weight. The square root of this weighted sum of squares was the estimated regression residual standard deviation. The results from polynomial regression models relating blood pressure to age and height Z-score among non-overweight children in the ERICA database are shown in Table S1.

The regression equations were then used to estimate the expected systolic and diastolic BP at specific age and height percentiles. Obtained polynomial coefficients were applied to compute specific 50th, 90th, 95th, and 99th age and height BP percentiles.

The variables were analyzed by using the software Stata 14.0 (StataCorp., College Station, TX, USA) significance level was set as 5%.

Results

A total of 73,399 adolescents were included in this analysis of the ERICA study (a description of the response rate and the characteristics of people who did or did not take part in the study was provided elsewhere[27]). From those, 25.5% (95% CI: 24.4–26.6) were identified as being overweight (17.1%

Table 1 Distribution of non-overweight adolescents by selected variables.

Variable	Overall	Females	Males
Sample distribution	100	50.0 (49.3–50.6)	50.0 (49.4–50.7)
Age distribution			
12 years	16.4 (16.0–16.9)	16.8 (16.2–17.4)	16.1 (15.5–16.7)
13 years	16.8 (16.4–17.3)	16.7 (16.0–17.4)	16.9 (16.4–17.5)
14 years	17.7 (17.3–18.0)	17.3 (16.8–17.7)	18.1 (17.5–18.6)
15 years	18.0 (17.7–18.3)	18.1 (17.8–18.5)	17.9 (17.4–18.4)
16 years	17.0 (16.5–17.4)	16.8 (16.2–17.4)	17.1 (16.6–17.7)
17 years	14.1 (13.8–14.4)	14.3 (13.8–14.8)	13.8 (13.3–14.4)
Skin color			
White	37.8 (36.2–39.5)	38.2 (36.3–40.2)	37.4 (35.6–39.2)
Black	8.0 (7.4–8.8)	6.5 (5.8–7.2)	9.6 (8.6–10.7)
Brown	48.8 (47.4–50.1)	51.2 (49.5–52.9)	46.4 (44.7–48.1)
Asian	2.2 (1.9–2.5)	2.3 (2.0–2.7)	2.1 (1.7–2.5)
Indigenous	0.7 (0.5–0.8)	0.4 (0.3–0.6)	0.9 (0.7–1.2)
Not declared	2.5 (2.2–2.8)	1.4 (1.2–1.7)	3.6 (3.2–4.1)
Public school	84.2 (79.9–87.7)	84.1 (79.7–87.7)	84.2 (79.9–87.8)
Alcohol consumption	22.2 (21.1–23.3)	22.2 (20.8–23.7)	22.1 (20.5–23.8)
Physically inactive	54.8 (53.7–55.8)	71.6 (70.3–73.0)	37.9 (36.5–39.4)
Smoking	2.6 (2.2–2.9)	2.2 (1.8–2.7)	2.9 (2.4–3.5)
Height (m)	1.62 (1.62–1.63)	1.59 (1.59–1.59)	1.66 (1.66–1.66)
Weight (kg)	51.1 (50.9–51.3)	49.4 (49.2–49.6)	52.8 (52.5–53.1)
BMI (kg/m^2)	19.3 (19.2–19.3)	19.5 (19.4–19.6)	19.0 (19.0–19.1)
WC (cm)	67.4 (67.3–67.6)	66.7 (66.5–66.8)	68.2 (68.0–68.4)
SBP[a] (mmHg)	108.6 (108.3–109.0)	105.9 (105.5–106.4)	111.4 (110.9–111.8)
DBP[b] (mmHg)	64.9 (64.6–65.2)	65.4 (65.0–65.8)	64.4 (64.1–64.7)
Heart rate (bpm)	81.3 (80.8–81.8)	84.2 (83.7–84.7)	78.4 (77.9–78.9)

Values given as proportion (95% CI) or mean (95% CI).
BMI, body mass index; WC, waist circumference.
[a] SBP, mean of second and third systolic blood pressure measurements.
[b] DBP, mean of second and third diastolic blood pressure measurements.

[95% CI: 16.3–18.0]) and obese (8.4% [95% CI: 7.9–8.9]), and were excluded from the construction of the BP percentiles (a table describing the overall ERICA sample, non-overweight, and overweight samples is provided as an online supplement – Table S2).

Non-overweight adolescents represented 74.5% (95% CI: 73.3–75.6) of the total sample. Age distribution across the sample varied from 14.1% (95% CI: 13.8–14.4) among those aged 17 years to 18.0% (95% CI: 17.7–18.3) in those 15 years old. The majority of the non-overweight sample was from public schools and was sedentary. Reported skin colors of brown and white were most frequent. When sex was assessed separately, the proportions of blacks and indigenous were higher in males, while the proportion of those who reported themselves as brown was higher in female adolescents. Additionally, the percentage of female adolescents physically inactive was higher than males. The overall description of the sample used to build the reference values for office BP, and its sex stratification is reported in Table 1.

BP percentiles from non-overweight adolescents by age and height are shown in Tables 2 and 3. BP increased in adolescents with both age and height percentiles. Systolic BP growth patterns were more marked in males than in females, along all height percentiles. The same pattern was not observed for diastolic BP.

The comparisons of our study's 95th BP percentiles for median height with the available international normative values obtained with two auscultatory and two oscillometric devices are presented in Fig. 1. For females, these systolic BP results were slightly lower than the four compared references. For diastolic BP, the results were between the two other studies conducted using oscillometric devices and lower than the two studies using auscultatory techniques.

For males, this study's systolic BP 95th percentiles for median heights were between the two higher values (using oscillometric devices) and the two lower ones (using auscultatory devices). For diastolic BP in males, the 95th percentiles for median height pattern was similar to that in females (values between studies conducted with oscillometric devices and lower than studies using auscultatory sphygmomanometers).

Discussion

This study provided sex, age, and height-specific BP percentiles using data from a large, nationally representative

Table 2 Office blood pressure values obtained with oscillometric devices in Brazilian female adolescents.

		Systolic blood pressure (mmHg)							Diastolic blood pressure (mmHg)						
		Height percentile							Height percentile						
Age (years)	BP percentile	5th	10th	25th	50th	75th	90th	95th	5th	10th	25th	50th	75th	90th	95th
12	50th	100	101	102	103	104	105	106	62	62	63	64	64	65	66
	90th	112	113	114	115	116	117	118	71	72	72	73	74	75	76
	95th	115	116	118	119	120	120	122	74	74	75	76	77	77	78
	99th	122	123	124	125	126	127	128	79	80	80	81	82	82	83
13	50th	102	104	105	105	107	108	109	63	63	64	65	65	66	67
	90th	114	116	117	117	119	120	121	72	73	73	74	75	76	76
	95th	118	119	120	121	122	123	124	75	76	76	77	78	78	79
	99th	124	125	126	127	128	129	131	80	81	81	82	83	83	84
14	50th	104	105	106	107	108	109	110	64	65	65	66	67	67	68
	90th	116	117	118	119	120	121	122	74	74	75	75	76	77	78
	95th	119	120	121	122	123	124	126	76	77	77	78	79	80	80
	99th	126	127	128	129	130	131	132	81	82	82	83	84	85	85
15	50th	105	106	107	108	109	110	111	65	66	66	67	68	68	69
	90th	117	118	119	120	121	122	123	74	75	76	76	77	78	79
	95th	120	121	122	123	124	125	127	77	78	78	79	80	80	81
	99th	127	128	129	130	131	132	133	82	83	83	84	85	85	86
16	50th	105	107	107	108	110	111	112	65	66	67	67	68	69	70
	90th	117	119	119	120	122	123	124	75	76	76	77	78	78	79
	95th	121	122	123	124	125	126	127	78	78	79	79	80	81	82
	99th	127	128	129	130	131	132	134	83	83	84	84	85	86	87
17	50th	106	107	108	109	110	111	112	66	66	67	68	68	69	70
	90th	118	119	120	121	122	123	124	75	76	76	77	78	79	80
	95th	121	122	123	124	125	126	128	78	79	79	80	81	81	82
	99th	127	129	130	131	132	133	134	83	84	84	85	86	86	87

BP, blood pressure.

Table 3 Office blood pressure values obtained with oscillometric devices in Brazilian male adolescents.

Age (years)	BP percentile	Systolic blood pressure (mmHg) Height percentile 5th	10th	25th	50th	75th	90th	95th	Diastolic blood pressure (mmHg) Height percentile 5th	10th	25th	50th	75th	90th	95th
12	50th	98	99	101	103	106	107	110	60	60	61	62	63	63	65
	90th	111	113	114	117	119	120	123	70	70	71	72	73	73	75
	95th	114	116	118	120	122	124	126	73	73	74	75	76	76	77
	99th	121	123	125	127	129	131	133	78	79	79	80	81	82	83
13	50th	101	103	105	107	109	111	112	61	61	62	63	64	64	65
	90th	114	116	118	120	122	124	125	71	71	72	73	74	74	75
	95th	118	120	122	124	126	127	129	73	74	75	76	77	77	78
	99th	125	127	129	131	133	134	136	79	80	80	81	82	82	83
14	50th	106	108	110	112	114	115	117	62	63	64	64	65	66	66
	90th	119	121	123	125	127	128	130	72	73	74	74	75	76	76
	95th	122	125	127	129	131	132	133	75	76	77	77	78	78	79
	99th	129	132	134	136	138	139	140	80	81	82	82	83	84	84
15	50th	110	112	114	116	118	119	120	63	64	65	66	67	67	67
	90th	123	125	127	129	131	132	133	73	74	75	76	77	77	77
	95th	126	129	131	133	134	136	137	76	77	78	79	79	80	80
	99th	133	136	138	140	141	143	144	82	82	83	84	85	85	86
16	50th	112	114	116	118	119	121	122	65	65	66	67	67	68	69
	90th	125	127	129	131	132	134	136	75	75	76	77	77	78	79
	95th	129	131	133	135	136	137	139	77	78	79	80	80	81	82
	99th	136	138	140	142	143	144	146	83	84	84	85	86	86	87
17	50th	114	116	118	120	122	123	125	65	66	67	68	68	69	70
	90th	127	129	131	133	135	136	138	75	76	77	78	78	79	80
	95th	131	133	135	137	138	139	141	78	79	80	80	81	82	83
	99th	138	140	142	144	145	146	148	84	84	85	86	86	87	88

BP, blood pressure.

population sample of school-aged adolescents in Brazil. To the authors' knowledge, ERICA is the first Brazilian study providing reference BP values for adolescents using a validated oscillometric device. In addition to being the largest study designed to construct BP percentiles for adolescents conducted heretofore, it used rigorous and standardized methodology for data collection. Because of the strong relationship between BP and overweight/obesity,[28] the inclusion of overweight subjects would have raised the threshold for normal BP and, as a result, obesity-related BP elevations would be more difficult to detect.[14] To avoid this, overweight adolescents were excluded from the reference population. The same exclusion criterion has been consistently applied in studies assessing BP percentiles in children and adolescents.[1,6,12–14,29]

Reference values describe a population sample expected to be representative with respect to the parameter evaluated. It remains to be evaluated to what extent the results can be used for other races or continents.[30] From that perspective, it is important that other countries or at least regions with similar population characteristics produce their own BP percentile tables for adolescents using oscillometric devices. Until all these tables are available, the results provided in the present study may be used as reference values considering the large sample size and the ethnic heterogeneity of the Brazilian population.[31]

Blood pressure values obtained with oscillometric devices are considerably higher than those resulting from the auscultatory technique.[7] The present study reported lower systolic and diastolic BP percentiles (with the exception of systolic BP in male adolescents) compared with the BP percentiles obtained with auscultatory devices. These results can be explained by the fact that in ERICA the mean of second and third readings was used to compute BP percentiles, which is on average 1–2 mmHg lower than the first BP reading.[32] This methodology is consistent with the two studies that used oscillometric devices[12,14] which were used as references for comparison. Oppositely the studies using auscultatory technique that were compared to these results used either only the first reading[13] or a mixture of the first and the mean of the second/third readings.[1]

National HTN guidelines play an important role in helping the healthcare community to diagnose and treat the disease. The Brazilian Guidelines of Arterial Hypertension,[8] which in 2016 reached its seventh edition, is a valued and often revised document. BP references used in the Hypertension in Children and Adolescents chapter of these guidelines were developed using United States data.[24] Since the current

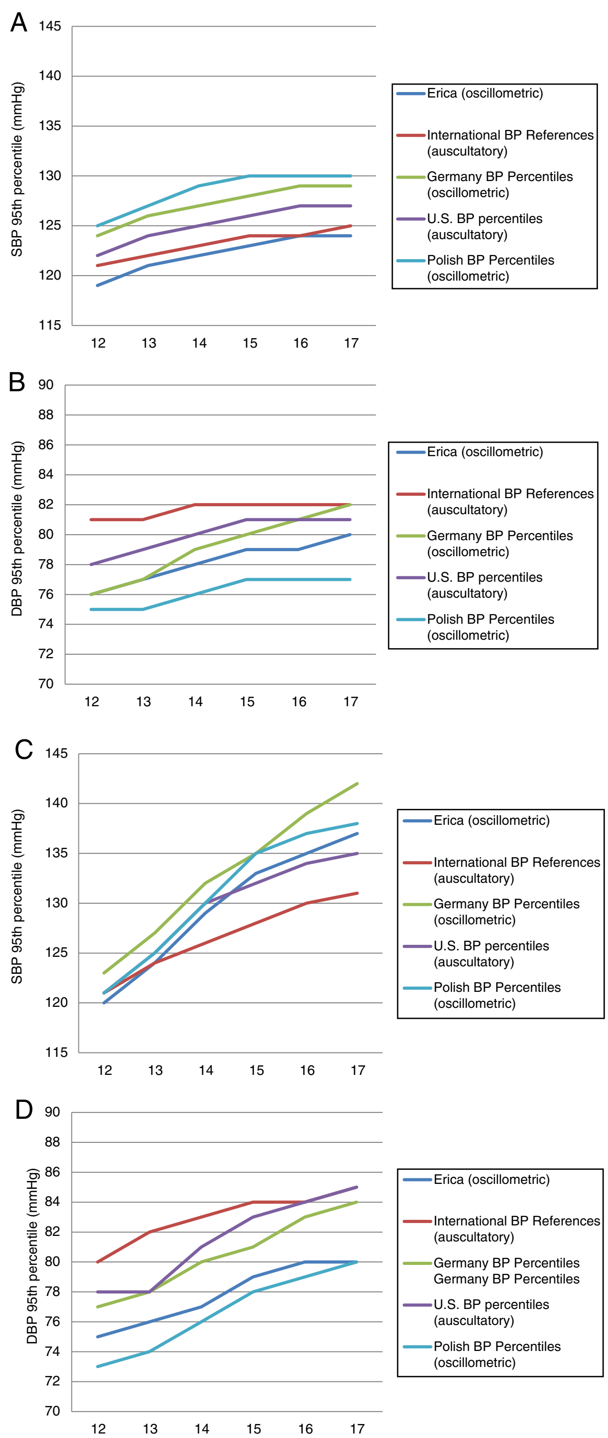

Figure 1 Comparison of the 95th systolic and diastolic blood pressure percentiles at median height by age in five studies for female (A and B) and male adolescents (C and D).

study is presenting for the first time reference values for office blood pressure in normal weight Brazilian adolescents, consideration should be given to using them in the following versions of the Brazilian hypertension guidelines.

The accuracy of a device is mandatory in any BP measurement method,[33] especially considering studies providing reference values for children and adolescents. Oscillometric BP monitors need to be tested in validation studies with specific protocols, and although a considerable number of these devices are available in the market, most of them were not successfully subjected to validation studies.[34] The present study used a device that was validated for adolescents' systolic and diastolic BP using two different international protocols (Association for the Advancement of Medical Instrumentation and European Society of Hypertension International Protocol).[25]

The European Society of Hypertension guidelines for the management of high BP in children and adolescents (2016)[7] proposed that the BP cut-offs for 16 years and older adolescents should no longer be based on the 95th percentile, but on the absolute cut-off used for adults (BP $\geq$ 140/90 mmHg). Alternatively, the Clinical Practice Guideline for Screening and Management of High Blood Pressure in Children and Adolescents from the American Academy of Pediatrics (2017)[9] proposed as a definition of HTN for adolescents aged 12 and 13 years BP values $\geq$ 95th percentile or $\geq$130/80 mmHg (whichever is lower), and for adolescents aged > 13 years, BP values $\geq$ 130/80 mmHg. This difference is probably related to the absence of data to identify a specific level of BP in childhood that results in adverse cardiovascular outcomes in adulthood.[9] Because there is no clear consensus in adolescents' definition of HTN, it was decided to just report the reference values for office blood pressure using oscillometric devices in normal weight adolescents, without calling into question the overall merit of the definition of HTN.

A limitation of this study is that it provides reference values for office BP using oscillometric devices only in non-overweight adolescents (12–17 years range) as the sample selection was restricted to this age group. Normalcy BP references for younger Brazilians are also required and thus studies including this age group (<12 years) are needed.

Although some studies have found an independent effect of sexual maturity on BP,[35,36] it has been postulated that the effect of sexual maturity mainly operates through height and body fat.[37] Thus, even with the debate about the possible role of sexual maturation on BP, knowledge about the exact influence of sex hormones on BP is rather poor.[38] Given that, and the additional objective to make the results more comparable with other adolescents' BP percentiles tables, the authors did not stratify our results according to pre- and post-puberty.

The recommended method of BP measurement in children and adolescents is still the auscultatory. Oscillometric devices are a suitable alternative for initial screening[39] and their increasing use, not only for home BP measurements but also in clinics, justifies efforts to construct BP reference values based on the oscillometric technique with the use of validated devices.[12] Although country-specific BP percentiles for adolescents using oscillometric devices have been established in some countries,[12,14,29,40] it is important that more countries and regions construct their own percentiles using standardized methodologies. Thus, a globally unified BP reference for defining elevated BP in children and adolescents using oscillometric devices can be developed, which will ultimately enable international comparisons of pediatric HTN prevalence between countries and regions.

In conclusion, the references presented here are, to the authors knowledge, the first Brazilian adolescents' BP references by age and height based on measurements performed with a validated oscillometric device and following an appropriate methodology for data collection. The proposed reference values were stratified by sex, age, and height, and were not influenced by the prevalence of overweight children in the reference population.

Funding

The ERICA study was supported by the Brazilian Ministry of Health (Science and Technology Department) and the Brazilian Ministry of Science and Technology (Financiadora de Estudos e Projetos/FINEP and Conselho Nacional de Pesquisa/CNPq) (grants FINEP: 01090421, CNPq: 565037/2010-2, 405009/2012-7 and 457050/2013-6).

Conflicts of interest

The authors declare no conflicts of interest.

Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at doi:10.1016/j.jped.2018.09.003.

References

1. Xi B, Zong X, Kelishadi R, Hong YM, Khadilkar A, Steffen LM, et al. Establishing international blood pressure references among nonoverweight children and adolescents aged 6 to 17 years. Circulation. 2016;133:398–408.
2. Han JC, Lawlor DA, Kimm SY. Childhood obesity. Lancet. 2010;375:1737–48.
3. Jardim TV, de Souza Carneiro C, Morais P, Mendonça KL, Póvoa TIR, Nascente FM, et al. Home blood pressure normalcy in non-European adolescents. J Hypertens. 2018;36:61–8.
4. Kollias A, Dafni M, Poulidakis E, Ntineri A, Stergiou GS. Out-of-office blood pressure and target organ damage in children and adolescents: a systematic review and meta-analysis. J Hypertens. 2014;32:2315–31 [discussion 31].
5. Chen X, Wang Y. Tracking of blood pressure from childhood to adulthood: a systematic review and meta-regression analysis. Circulation. 2008;117:3171–80.
6. Barba G, Buck C, Bammann K, Hadjigeorgiou C, Hebestreit A, Mårild S, et al. Blood pressure reference values for European non-overweight school children: the IDEFICS study. Int J Obes. 2014;38:S48–56.
7. Lurbe E, Agabiti-Rosei E, Cruickshank JK, Dominiczak A, Erdine S, Hirth A, et al. 2016 European Society of Hypertension guidelines for the management of high blood pressure in children and adolescents. J Hypertens. 2016;34:1887–920.
8. Malachias MV, Koch V, Colombo C, Silva S, Guimaraes IC, Nogueira PK. 7th Brazilian Guideline of Arterial Hypertension: chapter 10 – hypertension in children and adolescents. Arq Bras Cardiol. 2016;107:53–63.
9. Flynn JT, Kaelber DC, Baker-Smith CM. Clinical practice guideline for screening and management of high blood pressure in children and adolescents. Pediatrics. 2017:140.
10. Pickering TG, Hall JE, Appel LJ, Falkner BE, Graves J, Hill MN. Recommendations for blood pressure measurement in humans and experimental animals: part 1: blood pressure measurement in humans: a statement for professionals from the Subcommittee of Professional and Public Education of the American Heart Association Council on High Blood Pressure Research. Circulation. 2005;111:697–716.
11. Jardim TV, Gaziano TA, Nascente FM, Carneiro CS, Morais P, Roriz V, et al. Office blood pressure measurements with oscillometric devices in adolescents: a comparison with home blood pressure. Blood Pressure. 2017;26:572–8.
12. Kulaga Z, Litwin M, Grajda A, Kułaga K, Gurzkowska B, Góźdź M, et al. Oscillometric blood pressure percentiles for Polish normal-weight school-aged children and adolescents. J Hypertens. 2012;30:1942–54.
13. Rosner B, Cook N, Portman R, Daniels S, Falkner B. Determination of blood pressure percentiles in normal-weight children: some methodological issues. Am J Epidemiol. 2008;167:653–66.
14. Neuhauser HK, Thamm M, Ellert U, Hense HW, Rosario AS. Blood pressure percentiles by age and height from nonoverweight children and adolescents in Germany. Pediatrics. 2011;127:e978–88.
15. Bloch KV, Szklo M, Kuschnir MC, Abreu Gde A, Barufaldi LA, Klein CH, et al. The Study of Cardiovascular Risk in Adolescents – ERICA: rationale, design and sample characteristics of a national survey examining cardiovascular risk factor profile in Brazilian adolescents. BMC Publ Health. 2015;15:94.
16. Vasconcellos MT, Silva PL, Szklo M, Kuschnir MC, Klein CH, Abreu Gde A, et al. Sampling design for the Study of Cardiovascular Risks in Adolescents (ERICA). Cad Saude Publ. 2015;31:921–30.
17. Um estado das categorias de classificação de cor ou raça. In: (IBGE) IBdGeE, (ed.). Rio de Janeiro: IBGE; 2008.
18. National Center for Chronic Disease P, Health Promotion Office on S and Health. Reports of the Surgeon General. Preventing tobacco use among youth and young adults: a report of the surgeon general. Atlanta (GA): Centers for Disease Control and Prevention (US); 2012.
19. Global Youth Tobacco Survey Collaborating Group. Differences in worldwide tobacco use by gender: findings from the Global Youth Tobacco Survey. J Sch Health. 2003;73:207–15.
20. Coutinho ES, França-Santos D, Magliano Eda S, Bloch KV, Barufaldi LA, Cunha Cde F, et al. ERICA: patterns of alcohol consumption in Brazilian adolescents. Rev Saude Publ. 2016;50:8s.
21. de Farias JC Jr, Lopes Ada S, Mota J, Santos MP, Ribeiro JC, Hallal PC. Validity and reproducibility of a physical activity questionnaire for adolescents: adapting the Self-Administered Physical Activity Checklist. Rev Bras Epidemiol. 2012;15:198–210.
22. Biddle S, Cavill N, Sallis J. Young and active? Young people and health-anhancing physical activity-evidence and implications. London: Health Education Authority; 1998.
23. de Onis M, Onyango AW, Borghi E, Siyam A, Nishida C, Siekmann J. Development of a WHO growth reference for school-aged children and adolescents. Bull World Health Org. 2007;85:660–7.
24. National High Blood Pressure Education Program Working Group on High Blood Pressure in Children and Adolescents. The fourth report on the diagnosis, evaluation, and treatment of high blood pressure in children and adolescents. Pediatrics. 2004;114:555–76.
25. Stergiou GS, Yiannes NG, Rarra VC. Validation of the Omron 705 IT oscillometric device for home blood pressure measurement in children and adolescents: the Arsakion School Study. Blood Press Monit. 2006;11:229–34.
26. Bloch KV, Klein CH, Szklo M, Kuschnir MC, Abreu Gde A, Barufaldi LA, et al. ERICA: prevalences of hypertension and obesity in Brazilian adolescents. Rev Saude Publ. 2016;50:9s.
27. da Silva TL, Klein CH, Souza Ade M, Barufaldi LA, Abreu Gde A, Kuschnir MC, et al. Response rate in the Study of Cardiovascular Risks in Adolescents – ERICA. Rev Saude Publ. 2016;50:3s.
28. Sorof J, Daniels S. Obesity hypertension in children: a problem of epidemic proportions. Hypertension. 2002;40:441–7.
29. Munkhaugen J, Lydersen S, Wideroe TE, Hallan S. Blood pressure reference values in adolescents: methodological aspects and suggestions for Northern Europe tables based on

the Nord-Trondelag Health Study II. J Hypertens. 2008;26: 1912–8.
30. Soergel M, Kirschstein M, Busch C, Danne T, Gellermann J, Holl R, et al. Oscillometric twenty-four-hour ambulatory blood pressure values in healthy children and adolescents: a multicenter trial including 1141 subjects. J Pediatr. 1997;130: 178–84.
31. Saloum de Neves Manta F, Pereira R, Vianna R, Saloum de Neves Manta F, Pereira R, Vianna R, et al. Revisiting the genetic ancestry of Brazilians using autosomal AIM-Indels. PLoS One. 2013;8:e75145.
32. Gillman MW, Cook NR. Blood pressure measurement in childhood epidemiological studies. Circulation. 1995;92:1049–57.
33. O'Brien E, Asmar R, Beilin L, Imai Y, Mallion JM, Mancia G, et al. European Society of Hypertension recommendations for conventional, ambulatory and home blood pressure measurement. J Hypertens. 2003;21:821–48.
34. Stergiou GS, Boubouchairopoulou N, Kollias A. Accuracy of automated blood pressure measurement in children: evidence, issues, and perspectives. Hypertension. 2017;69:1000–6.
35. Cho SD, Mueller WH, Meininger JC, Liehr P, Chan W. Blood pressure and sexual maturity in adolescents: the Heartfelt Study. Am J Hum Biol. 2001;13:227–34.
36. Chen X, Wang Y. The influence of sexual maturation on blood pressure and body fatness in African-American adolescent girls and boys. Am J Hum Biol. 2009;21:105–12.
37. Leccia G, Marotta T, Masella MR, Mottola G, Mitrano G, Golia F, et al. Sex-related influence of body size and sexual maturation on blood pressure in adolescents. Eur J Clin Nutr. 1999;53:333–7.
38. Czubryt MP, Espira L, Lamoureux L, Abrenica B. The role of sex in cardiac function and disease. Can J Physiol Pharmacol. 2006;84:93–109.
39. Duncombe SL, Voss C, Harris KC. Oscillometric and auscultatory blood pressure measurement methods in children: a systematic review and meta-analysis. J Hypertens. 2017;35:213–24.
40. Sung RY, Choi KC, So HK, Nelson EA, Li AM, Kwok CW, et al. Oscillometrically measured blood pressure in Hong Kong Chinese children and associations with anthropometric parameters. J Hypertens. 2008;26:678–84.