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Original Article

Blood pressure to height ratio for screening hypertension among Indonesian adolescents

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Abstract

Background Pediatric hypertension is an emerging health issue due to its increasing prevalence. Age-, gender-, and height-specific blood pressure percentiles have been widely used as a primary tool for detection of hypertension in the pediatric population. However, this method is too complicated to be used in general pediatric practice. The blood pressure to height ratio has been proposed as a practical tool to detect hypertension in children.

Objective To evaluate the accuracy of blood pressure to height ratio to be used as a tool for screening high blood pressure in Indonesian adolescents.

Methods This diagnostic test study using data from the *2013 Indonesia Basic Health Research* (*Riset Kesehatan Dasar/RISKESDAS*) report included 39,057 adolescents aged 15-18 years with complete data on age, gender, weight, height, and blood pressure. Blood pressure values were classified using the *2017 American Academy of Pediatrics* (AAP) hypertension clinical guidelines. Blood pressure to height ratio was calculated as mmHg/cm body height. A receiver-operator characteristics (ROC) curve analysis was performed to assess the accuracy of systolic blood pressure to height ratio (SBPHR) and diastolic blood pressure to height ratio (DBPHR) for screening high blood pressure in adolescents. The optimal cut-off points, sensitivity, and specificity of SBPHR and DBPHR were calculated.

Results The optimal cut-off points for defining elevated blood pressure in male adolescents aged 13-18 years were SBPHR 0.69 for male adolescents (sensitivity 96%, specificity 80%) and DBPHR 0.46 (sensitivity 97%, specificity 84%). In female adolescents, the optimal cut-offs were SBPHR 0.72 (sensitivity 97%, specificity 82%) and DBPHR 0.48 (sensitivity 98% and specificity 79%).

Conclusion Blood pressure to height ratio is a practical method with high sensitivity and specificity for detecting elevated blood pressure in Indonesian adolescents aged 15 to 18 years. **[Paediatr Indones. 2023;63:7-12; DOI: 10.14238/pi63.1.2022.7-12**].

Keywords: *adolescents; blood pressure to height ratio; hypertension; sensitivity; specificity*

Hypertension in children and adolescents has become a serious public health problem due to its increasing prevalence.[1,2] In 2017, the worldwide prevalences of hypertension and prehypertension in children and adolescents were 5-10% and 15-20%, respectively.[2] Primary hypertension frequently occurs among obese or overweight children. The increasing prevalence of hypertension is in line with the increase of body mass index (BMI).[3,4] Interestingly, the prevalence of hypertension in children with a high BMI in Southeast Asian countries was higher than that in children in the United States.[5] Hypertension in childhood and adolescence can lead to hypertension in adulthood and increases the risk of cardiovascular disease (CVD).[3] Early diagnosis of secondary hypertension in children is also important since the symptoms are usually not specific. Therefore, vigilant screening for hypertension in children and adolescents is needed to initiate intervention and prevent further hypertension-related disorders in early

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adulthood.[6,7]

The prevalence of hypertension in adolescents aged 15-17 years in Indonesia from the *2013 Indonesia Basic Health Research (Riset Kesehatan Dasar/ RISKESDAS)* was 5.3%.8 The "Seventh Report of the Joint National Committee on Prevention, Detection, Evaluation, and Treatment of High Blood Pressure" (JNC 7) classification by the *American Heart Association* was used to identify hypertension. In 2017, the *American Academic of Pediatrics* (AAP) established an update to the 2004 "Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents."[2] This report contained significant changes in the guidelines, including replacement of the term of "prehypertension" with "elevated blood pressure," and a simplified blood pressure classification in adolescents aged ≥13 years to align with adult guidelines.[2] In the *2017 AAP Hypertension Clinical Guidelines*, blood pressure values in adolescents ≥13 years of age were classified as normal (<120/<80 mmHg), elevated (120/<80 to 129/<80 mmHg), stage 1 hypertension (130/80 to 139/89 mmHg), or stage 2 hypertension (≥140/≥90 mmHg), regardless of gender.[2] In Indonesia, the diagnosis of hypertension has been defined according to the 2004 "Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents" classification. To the best of our knowledge, the prevalence of hypertension in children and adolescents based on the *2017 AAP Blood Pressure Guidelines* is still unknown in Indonesia.

Diagnosing hypertension in children and adolescents is more complicated and challenging than in adults, because blood pressure norms vary with age, gender, and height.[1,5,9] Thus, the need for a simple and practical tool to identify hypertension is important. In China, a novel study was conducted to identify hypertension in 11,661 children aged 6-17 years using blood pressure to height ratio (BPHR)10 and a similar study in Indonesia on 200 school children aged 9-11 years11 reported high feasibility and accuracy of BPHR for identification of hypertension in pediatric populations. We aimed to evaluate the feasibility and accuracy of BPHR as a screening tool for high blood pressure in Indonesian adolescents.

Methods

This cross-sectional study was conducted using the *2013 RISKESDAS* data. RISKESDAS is a national, large-scale health survey was designed to evaluate the performance of health programs that had been implemented in Indonesia. The data were taken from all regions in Indonesia, with representation to the district level.[8] Health information of adolescents aged 15-18 years in Indonesia were used and analyzed in this study, consisting of data on age, gender, body weight, body height, and blood pressure. Blood pressure and anthropometric data (height and body weight) for all subjects in the *2013 RISKESDAS* were measured by trained personnel using structured and standardized protocols.[12]

All blood pressure (BP) data were classified using the 2017 update to the *2004 AAP* "Fourth Report on the Diagnosis, Evaluation, and Treatment of High Blood Pressure in Children and Adolescents."[2] For adolescents aged ≥13 years, normal BP was defined as an average systolic BP (SBP) of <120 mmHg and/ or diastolic BP (DBP) <80 mmHg. Elevated blood pressure was identified as an average SBP of 120-129 mmHg and/or diastolic BP (DBP) <80 mmHg. Stage 1 hypertension was defined as average SBP of 130-139 mmHg and/or DPB of 80-89 mmHg, while average SBP ≥140 mmHg and/or DBP ≥90 mmHg indicated stage hypertension. Moreover, all anthropometric data were defined using the *2000 CDC Curve* to classify body weight according to age and gender into obese, well-nourished, and underweight, and height into tall stature (>95%), normal stature (between 5-95%), and short stature (<5%), according to age and gender. Blood pressure to height ratio was calculated as mmHg/cm body height.

Data from a total of 71,252 subjects aged 15-18 years were obtained from the *2013 RISKESDAS*. Adolescents with obesity (BMI >95th percentile), malnutrition (weight for height <70th percentile), tall stature (>95th percentile), or short stature (<5th percentile) based on the *2000 CDC Growth Curve* were excluded from the study. Thus, a total of 39,057 subjects (18,810 boys and 20,247 girls) were included. BPHRs were calculated, consisting of SBPHR [SBP (mmHg)/height (cm)] and DBPHR [DBP (mmHg)/ height (cm)]. This study had been approved by the Ethics Committee of Universitas Indonesia, Faculty of Medicine.

All data were analyzed using *SPSS version 17.0* (*IBM,* Armonk, New York) with statistical significance set at P<0.05. To test the usefulness of SBPHR and DBPHR to detect elevated blood pressure in adolescents, a receiver-operator characteristics (ROC) curve analysis was performed and the area under the curve (AUC) was measured to assess the diagnostic power of the tests. After the optimal cut-off points were determined, we determined the sensitivity and specificity of SBPHR and DBPHR to define elevated blood pressure.

Results

A total of 39,057 adolescents aged 15-18 years were included, consisting of 18,810 males and 20,247 females. The baseline characteristics of subjects are shown in **Table 1**. The prevalence of elevated blood pressure according to the 2017 AAP hypertension clinical guidelines was 22.7%, while the prevalence of stages 1 and 2 hypertension were 5.1% and 1.8%, respectively (**Table 2**).

Table 3 provides the characteristics of subjects according to gender, including weight, height, BMI, SBP, DBP, SBPHR, and DBPHR. In general, males displayed higher median weight and height, while females had higher median BMI. The SBP and DBP were higher in males compared to females, while higher SBPHR and DBPHR were observed in females.

Table 1. Baseline characteristics of subjects

Characteristics	(N=39,057)
Gender, n (%)	
Male	18,810 (48.2)
Female	20,247 (51.8)
Age group, n (%)	
15 years	10,821 (27.7)
16 years	9,933 (25.4)
17 years	9,853 (25.2)
18 years	8,450 (21.6)
Nutritional status, n (%	
Underweight	6,570 (16.8)
Well-nourished	30,612 (78.4)
Overweight	1,875 (4.8)
Height, n (%)	
5^{th} percentile	11,100 (28.4)
10^{th} percentile	13,343 (34.2)
25^{th} percentile	10,035 (28.4)
50^{th} percentile	3,715 (9.5)
75^{th} percentile	726 (1.9)
90^{th} percentile	138 (0.4)

The AUC values for the accuracy of both SBPHR and DBPHR in diagnosing elevated blood pressure in both gender groups ranged from 0.500 to 0.967. The AUCs of SBPHR in diagnosing elevated SBP (0.967 for males and 0.550 for females) was higher than that of DBPHR in diagnosing elevated DBP (0.500 for males and 0.500 for females) (**Table 4**).

The optimal cut-off points of SBPHR and DBPHR for identifying elevated SBP and DBP as well as corresponding sensitivity and specificity among adolescents are also shown in **Table 4**. The optimal SBPHR cut-off points for diagnosing elevated SBP were 0.69 in males and 0.72 in females, while the optimal DBPHR cut-off points for diagnosing elevated DBP were 0.46 in males and 0.48 in females. The sensitivity of this method was >90% for all, while the specificity of this method was >80% for all except for elevated DBP in females (79%), indicating that sensitivity was higher than specificity for elevated blood pressure in both genders.

Discussion

In our cross-sectional study of 39,057 adolescents, we found high prevalences of elevated blood pressure (22.7%) and hypertension (6.9%). The prevalence of hypertension in our study was higher than that of adolescents aged 15-17 years in the *2013 RISKEDAS* (5.3%).[8] This difference may have been due to the different criteria of hypertension used.

Blood pressure values according to age, gender, and height percentiles, have been widely used as the main tool to diagnose pediatric hypertension. A cohort study of 14,187 children and adolescents aged 3 to 18 years revealed that 507 (3.6%) subjects had hypertension, but only 131/507 (26%) had a diagnosis of hypertension documented in their electronic medical records. The use of complex diagnostic criteria for hypertension requiring age, gender, and height-specific percentile data was one reason for the high rate of undiagnosed hypertension.[13] Due to the complexities of measuring, interpreting, and monitoring of blood pressure in children, a simple and practical method to screen for hypertension in

Table 2. Characteristics of subjects' SBP and DBP based on *2017 AAP Hypertension Clinical Guidelines*

Blood pressure	Total (N=39,057)	Male (n=18,810)	Female (n=20,247)
SBP, n(%)			
Normal	27,503 (70.4)	11,536 (61.3)	15,967 (78.8)
Elevated blood pressure	8,884 (22.7)	5,260 (27.9)	3,624 (17.9)
Hypertension stage 1	1,984 (5.1)	1,462 (7.7)	522 (2.5)
Hypertension stage 2	686 (1.8)	552 (2.9)	134 (0.6)
DBP, n(%)			
Normal	26,112 (66.9)	12,362 (65.7)	13,750 (67.9)
Hypertension stage 1	10,355 (26.5)	5,118 (27.2)	5,237 (25.9)
Hypertension stage 2	2,590 (6.6)	1,330 (7.1)	1,260 (6.2)

Table 3. Characteristics of subjects according to gender (N=39,057)

Characteristics*	Male (n=18,810)	Female (n=20,247)
Weight, kg	53.85 (33.4-113.4)	48.57 (30-84.4)
Height, cm	166.08 (152.0-186.3)	156.47 (150.2-172.4)
BMI, kg/m^2	19.43 (14.09-36.57)	19.83 (11.88-30.25)
SBP, mmHg	116.16 (60-230)	109.78 (66-198)
DBP, mmHg	75.39 (30-143)	75.04 (30-140)
SBPHR, mmHg/cm	0.69 (0.37-1.35)	0.70 (0.42-1.31)
Normal	0.659 (0.37-0.77)	0.676 (0.42-0.79)
Elevated blood pressure	0.740 (0.66-0.83)	0.781 (0.70-0.86)
Hypertension stage 1	0.800 (0.71-1.02)	0.850 (0.77-1.04)
Hypertension stage 2	0.888 (0.77-1.35)	0.959 (0.82-1.31)
DBPHR, mmHg/cm	0.45 (0.18-0.86)	0.47 (0.20-0.87)
Normal	0.423 (0.18-0.51)	0.449 (0.20-0.53)
Hypertension stage 1	0.498 (0.44-0.67)	0.529 (0.46-0.68)
Hypertension stage 2	0.566 (0.49-0.86)	0.600 (0.53-0.87)

*in median (range)

Table 4. Areas under the ROC curve, the optimal cut-off SBPHR, and DBPHR for screening elevated blood pressure based on the *2017 AAP Hypertension Clinical Guideline*, and corresponding sensitivity and specificity according to gender

Variables	AUC	P value	95% CI	Cut-off points	Sensitivity	Specificity	PPV	NPV
Elevated SBP								
Male	0.967	<0.001	0.965 to 0.969	0.69	0.96	0.80	1.5	8.1
Female	0.550	<0.001	0.545 to 0.556	0.72	0.97	0.82	2.9	8.3
Elevated DBP								
Male	0.500	<1.000	0.505 to 0.517	0.46	0.97	0.84	2	4.6
Female	0.500	<1.000	0.483 to 0.495	0.48	0.98	0.79	1.7	8.0

CI=confidence interval; PPV=positive predictive value; NPV=negative predictive value

children and adolescents is needed. A novel study was conducted in China to identify hypertension in children using BPHR;[10] it has been replicated in other countries such as Italy,[14] Nigeria,[15] the United States,[16] Iran,[17] and The Congo.[18] It is noteworthy that the BPHR method for diagnosing hypertension works in different populations.

We analyzed for optimal gender-specific BPHR cut-off points. The optimal SBPHR cut-off values for elevated BP were 0.69 in males and 0.72 in females; the optimal DBPHR cut-off values were 0.46 in males and 0.48 in females. Our study results were consistent with a Chinese study,10 which found the optimal DBPHR cut-off points in adolescents aged 13-18 years for elevated blood pressure to be 0.46 for males and 0.48 for females. Similarly, a study in South-Eastern Turkey also noted optimal DBPHR cut-off values for hypertension of 0.4698 for males and 0.4848 for females.[19] Xi *et al.*[20] in China studied 11,661 children aged 6-17 years and reported that the optimal SBPHR thresholds for identifying elevated SBP in Chinese children aged 12- 17 years were 0.69 in boys and 0.72 in girls, while optimal DBPHR thresholds for elevated DBP were 0.49 in boys and 0.51 in girls.

Although we found high sensitivities of SBPHR and DBPHR in both boys and girls (>90%) to identify elevated BP, almost all our AUC results were not as high as those observed in a previous study (except SBPHR for males >0.9).[10] Our AUC of 0.50 to 0.967 was less satisfactory, indicating lower accuracy for detecting elevated BP in Indonesian adolescents. These results were in agreement with a previous study which stated that the accuracy of BPHR increased with higher degrees of hypertension.[21] The higher NPVs of BPHR in our study suggest that the BPHR method is unlikely to exclude people with hypertension. However, the low PPVs of optimal BPHR cut-off points indicated that many children with normal blood pressure would be misclassified as having elevated BP. Thus, BP values according to age, sex, and height-specific percentile, should have better precision for detecting hypertension in children, but the BPHR method still can be used as a screening tool for adolescents with high risk of hypertension.

To the best of our knowledge, our study is the first to examine BPHR as a method to detect elevated BP in Indonesian adolescents based on a representative population using the large-scale data of the *2013 RISKESDAS*. However, several limitations should be noted. First, subjects' BP was measured on only one visit. The *2017 AAP Hypertension Clinical Guideline* recommends determining BP in children as an average on at least ≥3 occasions.[2] Therefore, we may have overestimated the prevalence of elevated BP in Indonesian adolescents. Secondly, the 2017 AAP guideline simplifies the classification of BP in adolescents ≥13 years of age.[2] These new threshold values of elevated BP (previously called prehypertension) in adolescents aged ≥13 years might be an important reason for the difference in AUC results compared to other studies.[10,15] Finally, BP values in the *2013 RISKESDAS* were measured using digital oscillometric devices, which have implicit limitations despite being used commonly in healthcare settings.[22] The *2017 AAP Guidelines* recommended that if elevated BP is suspected on oscillometric method readings, confirmatory measurements should be obtained using auscultatory BP measurement.[2]

In conclusion, BPHR is a practical and straightforward diagnostic tool to detect elevated BP with very high sensitivity and good specificity. Blood pressure values according to age, sex, and height-specific percentiles, should be more precise for diagnosing hypertension in children because the height and age in growing children and adolescents are highly correlated with BP. However, due to the complexity of measuring, interpreting, and monitoring blood pressure in pediatric populations, we still recommend that BPHR be used to screen for elevated BP in Indonesian adolescents aged 15-18 years.

Conflict of interest

None declared.

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