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ARTICLE

Using blood pressure height index to define hypertension among secondary school adolescents in southwestern Uganda

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Abstract

Hypertension is the number one risk factor for cardiovascular diseases worldwide and yet its diagnosis among adolescents, based on blood pressure percentiles which are age, height, and sex-specific, is complex. Our study intended to determine the suitability of blood pressure height index in defining adolescent hypertension among secondary school adolescents aged 12–17 years in Mbarara municipality, southwestern Uganda. Our study used data of 485 secondary school adolescents of which 173 were boys. Receiver operating characteristic curve analysis was performed to assess the performance of systolic blood pressure height index (SBPHI) and diastolic blood pressure height index (DBPHI) for screening for adolescent prehypertension and hypertension. The optimal systolic/diastolic thresholds for defining prehypertension were 0.70/0.43 mmHg/cm in boys and 0.76/0.43 in girls. The corresponding values for hypertension were 0.78/0.43 and 0.77/0.48 mmHg/cm, respectively. The negative predictive values were much higher (all ≥ 95%) for prehypertension and hypertension, while the positive predictive value was 100% for hypertension in both sexes. In conclusion, Blood pressure height index is simple and accurate for screening for prehypertension and hypertension in adolescents aged 12–17 years hence can be used for early screening of adolescents at high risk of hypertension but not its diagnosis.

Introduction

Hypertension is the leading non-communicable disease and the number one risk factor for cardiovascular disease (CVD) worldwide [1, 2]. It is globally responsible for an estimated number of 7.5 million deaths a year and 57 million disability-adjusted life years [2, 3]. The global burden of hypertension has been increasing since 2000 especially in low and middle income countries [2]. Hypertension in adults of middle age and the elderly have been widely studied whereas in adolescents it is less understood. Although hypertension was previously considered a rare condition among adolescents, it has become more common and is increasing unexpectedly [4, 5]. The prevalence of hypertension among adolescents has been reported in several countries [4–13]. Undiagnosed and hence unmanaged hypertension has been positively correlated with the incidence of early target organ disease, left ventricular hypertrophy, stroke and coronary heart disease [14], which can exert significant stress on meager resources of low-income countries like Uganda. Unfortunately, diagnosis of hypertension in adolescents is complex for clinicians, children, and parents since it is based on blood pressure percentiles that are age, height and gender-specific with no single BP cut off as for adults. Research findings from various large sample surveys have shown that blood pressure height index (BPHI) could ease the definition of hypertension among adolescents [15–24]. Among adults, the limited studies have shown a positive association between blood pressure and height [25, 26]. Therefore, BPHI could ease the definition of hypertension, but literature on its general usability and accuracy is still sparse and limited to a few countries like China [23], Nigeria [18], Iran [20], India [19].

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The current study's impetus was the need to explore the usability and suitability of BPHI in defining hypertension among secondary school adolescents aged 12–17 years from Mbarara municipality, southwestern Uganda.

Methods

Study design and participants

The participants were part of a cross-sectional study conducted in three secondary schools in Mbarara municipality, southwestern Uganda between May and November 2018. The study involved a total of 616 adolescents aged 12–19 years. The study was approved by the Mbarara University of Science and Technology research ethics committee (IRB No. 18/03–18). The data analyzed for this paper is from those adolescents aged 12–17 years.

Measurements

Height was measured in centimeters using a wall mount height board with the participant shoeless and rear body parts touching the board while the head was facing forward. Weight was measured to the nearest 0.5 kg using a standard weighing scale (Seca 762, GmbH and Co. KG, Hamburg, Germany) and participants were encouraged to put on light clothing with no items in the pockets and shoeless. Body mass index (BMI) was computed as the ratio of the weight of an individual in kilograms to height squared in meters (kg/m^2).

Blood pressure (BP) was measured using a digital blood pressure monitor (Scian SP-582 Digital Blood Pressure Monitor, Honsun, Jiangsu, China (Mainland). Participants were prepared for BP measurement according to recommendations of the American Heart Association [27]. Each participant sat on a chair with back supported, feet on the floor, arm supported bychair amr and cubital fossa at heart level [27]. The cuff was placed at the bare upper arm, one inch above the bend of participant's elbow with tubing falling over the front center of the arm so that the sensor was correctly placed. The cuff was tightened evenly around the arm such that the skin would not pinch when the cuff inflated. The participant was asked to remain quiet as the machine began to measure and display SBP and DBP on the digital panel [28]. Three readings were recorded per participant in 5-min intervals of sitting rest and the average of the 2nd and 3rd readings in the session recorded for SBP and DBP [14]. Adolescents who had elevated BP (hypertensive) in the first session were identified and their blood pressure re-assessed after one week using the same procedure to confirm if their BP was persistently elevated.

Definition of hypertension

In this study, we used the age-specific, gender-specific, and height-specific BP percentile algorithm recommended by US National High Blood Pressure Education Program Working Group [4] as the gold standard for identifiation of participants with or without prehypertension and hypertension. Hypertension (stages 1 and 2) was defined as SBP/DBP ≥ 95th percentile. Severe hypertension (stage 2) was defined as SBP/DBP ≥ 99th percentile + 5 mm Hg. Prehypertension was defined as SBP/DBP ≥ 90th but <95th percentile or SBP/DBP ≥ 120/80 mm Hg[4].

Statistical analysis

Systolic blood pressure (mmHg)/height (cm) and the diastolic blood pressure (mmHg)/height (cm) indices were calculated. Receiver operating characteristic (ROC) curve analyses were performed to determine the accuracy of blood pressure height indices in defining hypertension among adolescents. The optimal thresholds of the blood pressure height index (BPHI) for identifying elevated arterial BP were selected as the values corresponding to the maximum of Youden's index on the ROC curve. Prehypertension and hypertension were then redefined by the determined optimal diastolic and systolic thresholds of BPHI, and compared with the gold standard blood pressure cutoffs [4]. The Area under the curve (AUC) and its 95% confidence interval (CI), as well as sensitivity, specificity, positive predictive value (PPV), and negative predictive value (NPV) were obtained to assess the performance of the determined systolic and diastolic BPHI optimal thresholds. All analyses were stratified by sex to cater for the physiological differences between girls and boys. Data were analyzed using Stata software version 13.0 (College Station, Texas, USA).

Results

Our study included a total of 485 adolescents, with 173 boys and 312 girls aged 12 to 17 years. The prevalence of prehypertension and hypertension using the definition by the US National High Blood Pressure Education Program Working Group in their Fourth report were 1.65% and 2.47%, respectively. Table 1 shows the characteristics of the study participants by sex.

In the overall sample, the optimal thresholds of systolic BPHI in defining systolic prehypertension (SBP ≥ 90th percentile but <95th percentile) and hypertension (SBP ≥ 95th percentile) were 0.74 mmHg/cm and 0.77 mmHg/cm, respectively. The correspoding areas under the curve (AUCs) for these systolic BPHI thresholds were 0.896 (Fig. 1) and 0.959 (Fig. 2) respectively. However, after

Table 1 Characteristics of study participants.

Variable	Girls ($n = 312$) Mean (SD)	Boys ($n = 173$) Mean (SD)	Total ($n = 485$) Mean (SD)
Age (years)	15.1 (1.5)	14.5 (1.5)	14.8 (1.6)
Weight (kg)	60.2 (7.6)	55.0 (7.3)	58.3 (7.9)
Height (cm)	156.9 (7.4)	157.2 (7.8)	156.9 (7.6)
Body Mass Index (kgm^{-2})	24.5 (2.3)	22.3 (2.9)	23.7 (2.8)
Systolic Blood Pressure (mmHg)	113.2 (7.3)	109.6 (10.9)	111.9 (8.9)
Diastolic Blood Pressure (mmHg)	65.4 (7.6)	64.3 (7.0)	65.0 (7.4)
SBPHI (mmHg/cm)	0.72 (0.05)	0.70 (0.06)	0.71 (0.06)
DBPHI (mmHg/cm)	0.42 (0.05)	0.41 (0.04)	0.41 (0.05)

SD standard deviation, *SBPHI* systolic blood pressure height index, *DBPHI* diastolic blood pressure height index

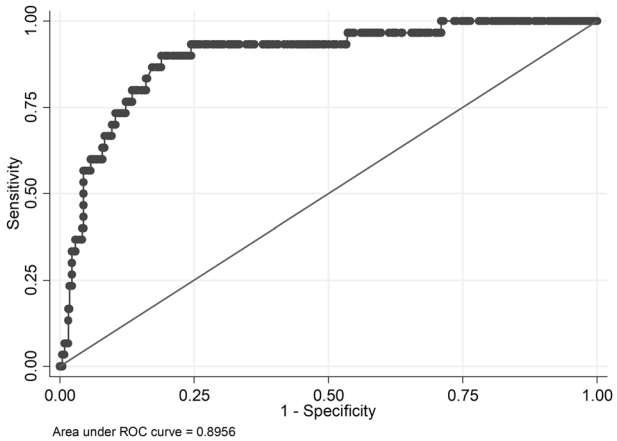


Fig. 1 ROC curve for SBPHI in defining prehypertension among adolescents.

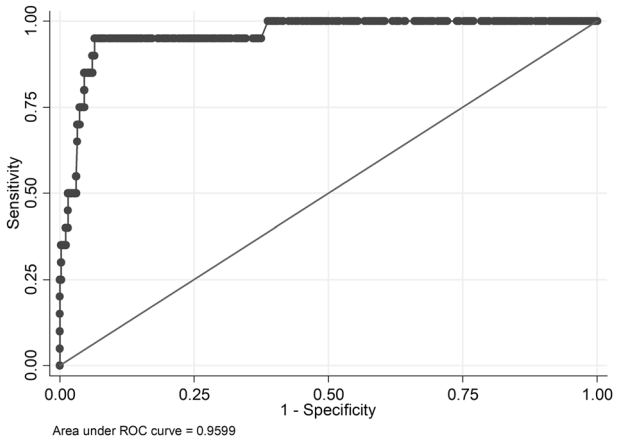


Fig. 2 ROC curve for SBPHI in defining hypertension among adolescents.

stratifying by sex, the cut off for prehypertension among the girls was slightly higher than among the boys while the cut off for hypertension was slightly higher among the boys (see Table 2).

Ability of diastolic BPHI to identify adolescents with or without diastolic hypertension (DBP ≥ 95th percentile) and pre-hypertension (DBP ≥ 90th percentile but <95th percentile) is summarized in Table 3. Among our study adolescents, the diastolic BPHI optimal threshold for prehypertension was similar in boys and girls (≥0.43 mmHg/cm) with differing AUCs of 0.908 and 0.852, respectively. The optimal threshold for diastolic hypertension was higher in girls (0.48 mmHg/cm) than in boys (0.44 mmHg/cm) while AUCs were similar (0.980 for girls and 0.984 for boys). Overall, the diastolic BPHI defined diastolic hypertension better than diastolic prehypertension. Using the systolic and diastolic BPHI thresholds determined in the study sample, the data driven prehypertension and hypertension status were assigned to participants and compared to the gold standard. The performance of the optimal thresholds of the SBPHI/DBPHI mmHg/cm for detecting hypertension was better than that for detecting prehypertension in both sexes (Figs. 3, 4). The poor performance of BPHI thresholds in detecting prehypertension was similar in boys and girls with AUC less than 0.5, specificity of 0.0% and PPV of 0.0% (Table 4). Despite the poor AUC, sensitivity and NPV of BPHI in detecting prehypertension were high in both boys and girls. Although BPHI registered better performance in detecting hypertension with high sensitivity, PPV, NPV and AUC was very low especially among the girls.

Discussion

Our study found that BPHI is suitable as a screening tool for identifying hypertension in a fairly large sample of adolescents 12 to 17 years old but weak at defining prehypertension. Our study findings indicate that BPHI would correctly classify all adolecents with hypertension. The high performance of BPHI in identification of adolescents with hypertension has been consistently reported across studies

Table 2 Optimal thresholds of systolic blood pressure height index for identifying elevated systolic blood pressure.

Category	Threshold (mmHg/cm)	Sensitivity	Specificity	AUC [95% CI]
Prehypertension				
Boys	≥0.70	0.889	0.659	0.843 [0.713–0.88]
Girls	≥0.76	0.857	0.859	0.931 [0.895–0.968]
Total	≥0.74	0.900	0.811	0.896 [0.838–0.953]
Hypertension				
Boys	≥0.78	1.00	0.969	0.984 [0.967–1.000]
Girls	≥0.77	0.917	0.923	0.939 [0.866–1.000]
Total	≥0.77	0.950	0.936	0.959 [0.922–0.997]

AUC Area under the curve, *CI* Confidence interval

Table 3 Optimal thresholds of diastolic blood pressure height index for identifying elevated diastolic blood pressure.

Category	Threshold (mmHg/cm)	Sensitivity	Specificity	AUC [95% CI]
Prehypertension				
Boys	≥0.43	0.889	0.884	0.908 [0.838–0.977]
Girls	≥0.43	1.000	0.738	0.852 [0.809–0.896]
Total	≥0.43	0.926	0.808	0.874 [0.838–0.909]
Hypertension				
Boys	≥0.44	1.000	0.926	0.984 [0.967–1.00]
Girls	≥0.48	1.000	0.955	0.980 [0.966–0.994]
Total	≥0.43	1.000	0.839	0.979 [0.966–0.993]

AUC area under the curve, *CI* confidence interval

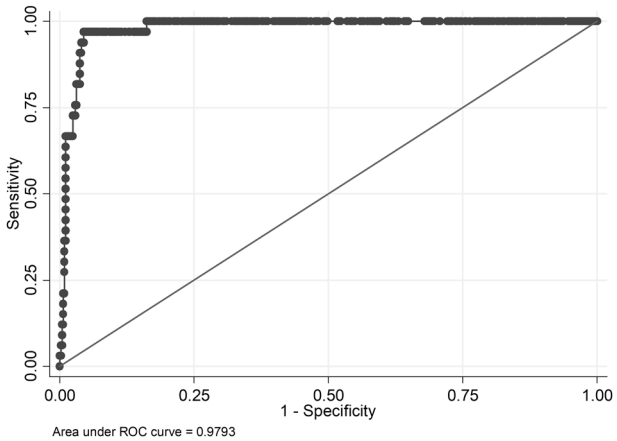


Fig. 3 ROC curve for DBPHI in defining prehypertension among adolescents.

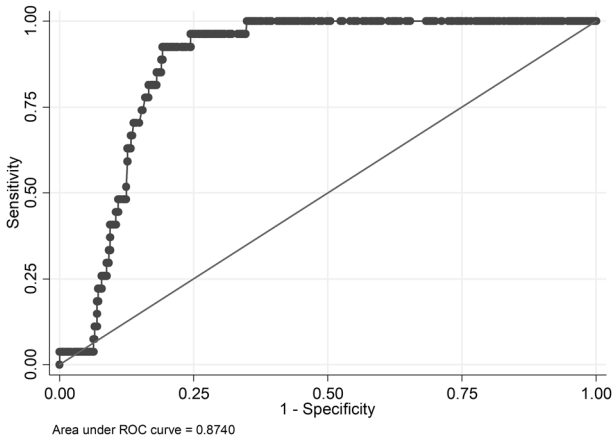


Fig. 4 ROC curve for DBPHI in defining hypertension among adolescents.

in Nigeria, China, India, and Iran suggesting that BPHI is a useful screening tool among adolescents. Therefere BPHI has potential to replace the complicated BP measurement tables which have often been reported to underdiagnose hypertension in adolescent populations [29]. The blood pressure height ratio was suggested as a simple and accurate index for identifying childhood and adolescent hypertension in several countries like Nigeria [18], China [24], and the United States [15]. The BPHI index, standardized for height and sex, is strongly and positively associated with SBP and DBP but is not related to age [30].This means it is not dependent on height or age. Our results agree with the several large sample size studies and have established the basic nationwide cutoffs for the BPHI index for detecting hypertension among adolescents with AUCs > 0.95.

Early indentification of at-risk adolescents with pre-hypertension is crucial to reduce the burden of the disease using appropriate intervrntions that retard progression to hypertension and the resultant CVD during adulthood [18]. However the overall performance of BPHI in detecting

Table 4 Overall performance of the selected optimal thresholds by sex.

Category	Threshold (mmHg/cm)	Sensitivity	Specificity	PPV	NPV	AUC [95% CI]
Prehypertension						
Boys	0.70/0.43	0.976	0.000	0.000	0.970	0.485 [0.472–0.498]
Girls	0.76/0.43	0.987	0.000	0.000	0.977	0.489 [0.480–0.497]
Hypertension						
Boys	0.78/0.43	1.000	0.583	1.000	0.969	0.985 [0.972–0.998]
Girls	0.77/0.48	1.000	0.278	1.000	0.958	0.979 [0.968–0.990]

PPV positive predictive value, *NPV* negative predictive value, *AUC* area under the curve

prehypertension in our study sample was poor despite the high specificity. BPHI, as demonstrated in the current study would not classify those with prehypertension as the AUC was way below 0.5 in both sexes. Even though optimal thresholds vary between studies, the poor positive predictive value of BPHI has also been reported among adolescents in India and in China among children 6 to 11 years old [31] and adolecents aged 12 to 17 years [32]. The low PPVs of optimal cutoffs suggest that many people with normal blood pressure would be misclassified as having prehypertension. Therefore BPHI index may not be used to replace the existing age-specific, gender-specific, and height-specific BP percentiles for diagnosing elevated BP falling bwtween the 90th and 95th percentile [29]. However the high NPVs and sensitivity of BPHI in detecting prehypertension in our study sample suggests the method is unlikely to leave out individuals with prehypertension but adolecents with a positive result would require further assessement using auscultation, be advised on lifestyle changes and followed up with ambulatory blood pressure monitoring. High sensitivty and low specificity of BPHI in dtecting hypertension has also been reported in studies of adolescents of 12 to 18 years among whom prevalence of prehypertension was more thant ten times the prevalence reported in the current study [23]. These findings suggest that BPHI could be a table tool for identifying prehypertension, less sensitive to prevalence variations.

The strength of this study is that it includes adolescents aged 12–17 years in a fairly large sample. In addition, the standardized BP protocols were used in the data collection, and health care workers were trained to take BP measurements for the study. Participants with eleveated blood pressue were assessed more than once at different occasions to minimize bias due to white coat hypertension. However, the prevalence of hypertension in our study was much lower than assumed during smaple size estimation which may have affected ROC anayses. In settings where prevalence of hypertension and prehypertension is low, more efficient study designs like case-contol or large scale surveys are recommended to further assess the utility BPHI in screening for the disease.

Conclusions

The BPHI is a simple and accurate index for screening for hypertension among adolescents aged 12 to 17 years.

Summary

What is known about the subject?

- The definition of hypertension in children using the age-, gender-, and height-specific blood pressure algorithm is complex. Blood pressure to height index was reported to easily identify hypertension in adolescents in China, Nigeria, Iran, and Italy among others.

What the study adds

- Blood pressure to height index is simple and accurate for screening for prehypertension and hypertension in adolescents aged 12 to 17 years in southwestern Uganda and can be used for early screening of adolescents for hypertension.

Data availability

The dataset and the Stata 13 do file are available on request from the corresponding author.

Acknowledgements The research used the data obtained from the general study titled "Prevalence of hypertension and diagnostic accuracy of resting pulse rate in relation to anthropometric indices among adolescents" as was approved by the Mbarara University of Science and Technology research ethics committee (IRB No.18/03–18). Therefore, the participants in this study and data collectors are highly appreciated.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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