

## BLOOD PRESSURE TO HEIGHT RATIO AS A SCREENING TOOL FOR HYPERTENSION IN SCHOOL GOING ADOLESCENTS AGED 12-18 YEARS IN BHAVNAGAR, GUJARAT

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### Abstract

**Background:** The age, gender, and height, percentiles requirements for the ‘gold-standard’ diagnosis of hypertension and prehypertension in adolescents make it time-consuming for clinicians and difficult-to-use by non-professionals. Simplified diagnostic tools are therefore needed. The use of blood pressure-to-height ratio (BPHR), systolic (SBPHR) and diastolic (DBPHR), has been reported in Han adolescents, and it requires validation in other racial groups. The diagnostic accuracy of SBPHR and DBPHR in Bhavnagar, Gujarat, India was therefore studied.

**Methods:** From a population of 1000 school going Caucasian adolescents aged 12-18 years from two schools; Blood pressures were measured using standard procedures. Hypertension and prehypertension (HTPHT) were defined according to the 2004 Working Group normative tables. ROC curve analyses were used to assess the diagnostic accuracy of BPHR in defining HTPHT in this population. Sex-specific threshold values for SBPHR and DBPHR were determined and thereafter used to define HTPHT. The sensitivity/specificity of this method was determined. Ethics Approval was obtained.

**Results:** The accuracy of SBPHR and DBPHR in diagnosing HTPHT, in both sexes, was >92%. The optimal threshold ratio for prehypertension was (systolic/ diastolic) 0.725/0.465 in boys and 0.745/0.465 in girls; while for hypertension, they were 0.765/0.495 in boys and 0.795/0.515 in girls. The sensitivity and specificity of this method was >88%.

**Conclusions:** The use of blood pressure-to-height ratio BPHR is valid, simple, and accurate in this population.

**Keywords:** Adolescents; Blood pressure-to-height ratio; Diagnosis; Prehypertension; Hypertension; Bhavnagar; School

### Introduction

Hypertension is an emerging health issue of importance in children and adolescents. Because HBP in childhood is often asymptomatic and, thus, is easily overlooked, almost 75% (90% with prehypertension) remain undiagnosed. However, given the complexity of defining paediatric-onset HBP (by sex, age, and height percentiles), technical issues involved (such as appropriate cuff size) and the paucity of available diagnostic guidance and data, it is understandable why detection rates are low.<sup>[1]</sup> Recently, Lu et al<sup>[2]</sup> developed novel criteria, using ratios of Systolic BP to Height (SBPHR) and Diastolic BP to Height (DBPHR) to identify HBP in Chinese Han adolescents. Diagnostic sensitivity and specificity were excellent with this method. We chose to evaluate this approach with following objectives in mind: to validate previous results via a sampling of adolescents from Bhavnagar, Gujarat, India; to determine applicability to children (12 to 18 years of age); to determine optimal ratio cut-off points, and to investigate

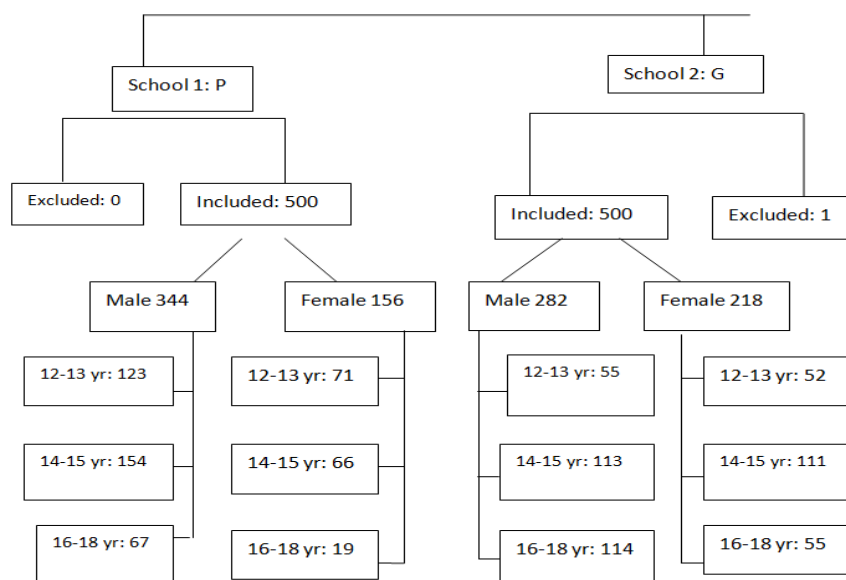
its utility in pediatric prehypertensive and hypertensive population.

### Materials and Methods:

The study was done at two schools of Bhavnagar during two months duration in 1000 students. From all subjects, written informed consent was obtained from the subject’s school heads after explanations of the purpose of the study. Subjects were chosen as per the exclusion and inclusion criteria. Two schools were selected in Bhavnagar (Metro city; population 600,000) from which 500 students aged 12-18 years were selected for this study. One school was a private school, another government school. So there were 500 students from affluent and 500 from relatively less affluent class (**fig 1**). Students from class seven to twelve were asked to come section-wise accompanied by their teachers. Once we realized that a significant number (around one-sixth) of similar-aged students had come, we asked for higher class students. We followed this same pattern in both the schools till we got 500 students

respectively from both. Children with known medical conditions or drug use causing dyslipidemia, diabetes, or

hypertension were excluded from the study.



**Figure 1: Flow chart Methodology**

**Height:** (for each subject) was measured, to the nearest 0.5 cm, using a non-elastic measuring tape, fastened to a vertical wall.

**Weight:** The students had to stand on bare feet and dressed in light clothing. An electronic weighing balance was used to measure each subjects' weight, to the nearest 0.1 kg.

**BP:** was measured by well-trained personnel from the bare right arm of participants, at the level of the heart, while participants remained seated with back support, after at least 5 min of rest. A calibrated mercury sphygmomanometer with appropriate cuff length and width was used. Measured twice in the right arm. The average was taken as mean BP

#### Measurements:

The age of the subjects was obtained from their school records. Height was measured, to the nearest 0.5 cm, using a non-elastic measuring tape, fastened to a vertical wall. The student was required to stand on bare feet. For the measurement of weight, the students had to stand on bare feet and dressed in light clothing. An electronic weighing balance was used to measure each subject's weight, to the nearest 0.1 kg. Using values from the height and weight measurements, Body Mass Index (BMI) was calculated using the formula  $BMI = \text{Weight (kg)} / [\text{height (m)}]^2$ . All the equipment was calibrated each morning according to the manufacturer's instructions. According to the standardized technique described by the American Heart Association, BP was measured by well-trained personnel from the bare right arm of participants, at the level of the heart, while participants remained seated with back support, after at least 5 min of rest. A calibrated mercury sphygmomanometer with appropriate cuff length and width

was used. Participants were advised to avoid coffee, tea, stimulant foods, smoking, and exercise for at least 30 min before the measurements. Two measurements were taken and averaged for analysis.

Blood pressure cuff width was 40–50% of the arm circumference. SBP was determined by the onset of the 'tapping' Korotkoff sounds (K1). The fifth Korotkoff sound (K5) was the definition of DBP. The following equations for BPHR were used:  $SBPHR = SBP \text{ (mm Hg)} / \text{height (cm)}$  and  $DBPHR = DBP \text{ (mm Hg)} / \text{height (cm)}$ .

#### Definitions:

The definition of hypertension was as follows: (1) Prehypertension- mean SBP or DBP  $\geq 90^{\text{th}}$  percentile and  $<95^{\text{th}}$  percentile. (2) Hypertension (stages 1 and 2) - mean SBP or DBP  $\geq 95^{\text{th}}$  percentile; and (3) Hypertension (stage 2) - mean SBP or DBP  $>99^{\text{th}}$  percentile + 5 mm Hg. All the adolescents' blood pressure measurements were compared with 2004 Working Group normative tables and percentiles to determine the final reported hypertensive status.

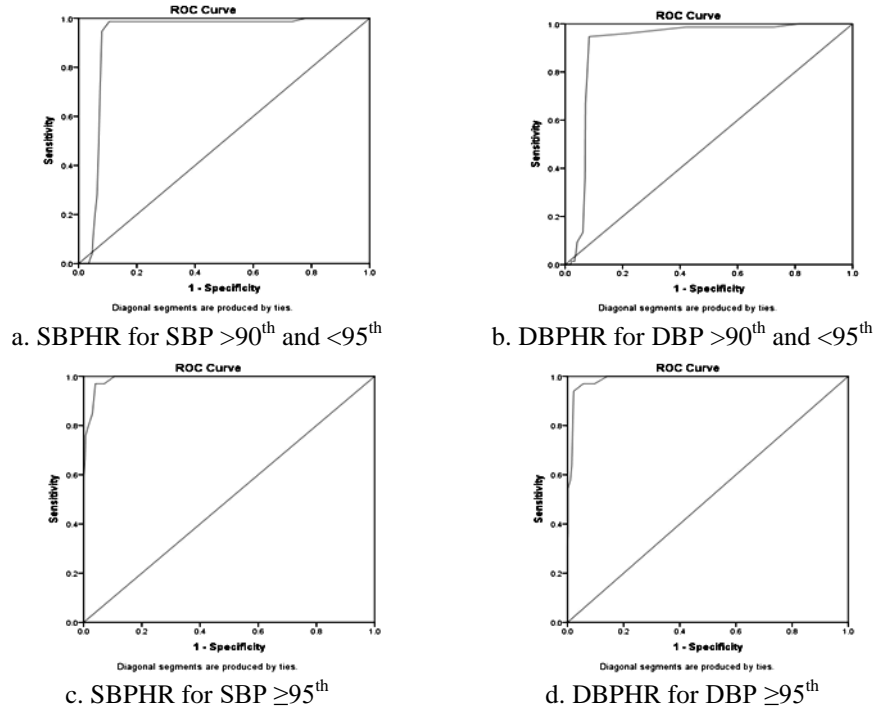
#### Statistical analysis:

Analyses were performed using SPSS version 23. The Pearson correlation coefficient was used to measure the strength of association between two variables. Using receiver-operating characteristic (ROC) analysis, the ROC curves of SBPHR and DBPHR were drawn to show how well they could separate subjects into groups with or without elevated SBP or DBP. ROC curves for boys and girls were plotted using measures of sensitivity and specificity based on various anthropometric cutoff values (fig 2). The ROC curves showed the overall discriminatory power of a diagnostic test over the whole range of testing values. The area under the curve (AUC) is a measure of the

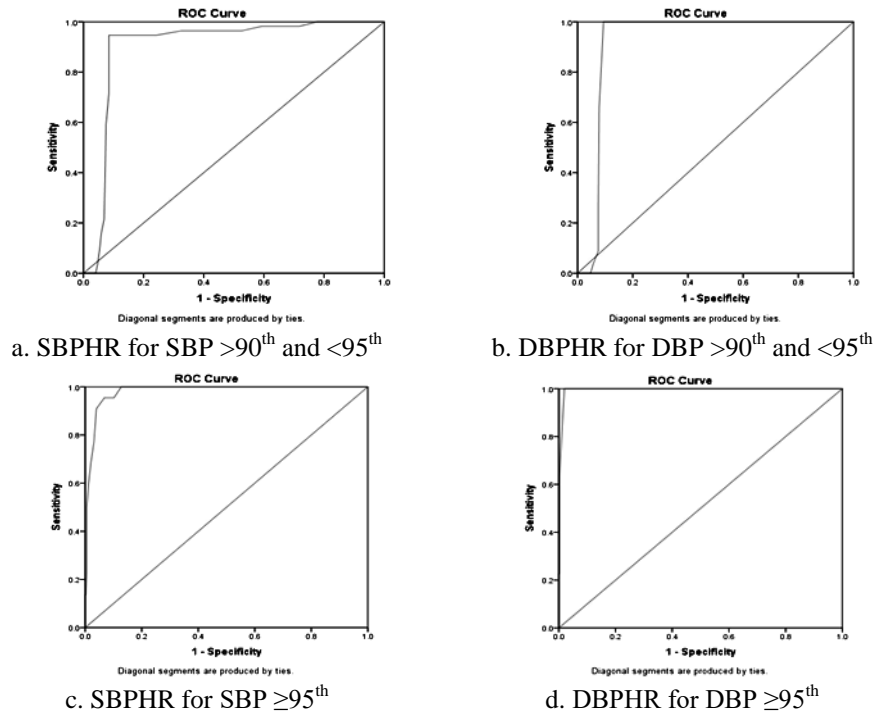
diagnostic power of a test. A perfect test will have an AUC of 1.0, and an AUC < 0.5 means the test performs No better than chance. A test with an AUC of  $\geq 0.85$  was considered an accurate test. The optimal sensitivity and specificity were the values yielding maximum sums from the ROC curves. After the cutoff points were determined,

hypertension and prehypertension were defined by SBPHR and DBPHR for both sexes, and the sensitivity and specificity of this method were calculated. Positive predictive value and the negative predictive value was calculated using Baye's theorem.

**2.1: Boys**



**2.2: Girls**



SBP systolic blood pressure, DBP diastolic BP, SBPHR SBP to height ratio, DBPHR DBP to height ratio

**Figure 2: ROC curves of Boys and Girls for SBPHR and DBPHR for prehypertension and hypertension**

( $x = 1 - \text{Specificity}$ ;  $y = \text{sensitivity}$ ) percentiles

**Result:**

The total student in the study was 1000, of which 625 were males and 375 females. The prevalence of hypertension was 5.5%. The prevalence of hypertension in boys was 4.8% (30) and in the girls was 5.8% (20). The prevalence of

prehypertension in boys and girls was 12% (75) and 14% (56) respectively. Stage 2 hypertension was present in 0.3% (3) males and 0.2% (2) females.

All AUC's were  $> 0.9$  in both sexes with a  $p$ -value  $< 0.05$ ; making this test both accurate and significant. (**Table 1**)

**Table 1: Areas under ROC curve of SBPHR and DBPHR for diagnosing elevated SBP and DBP defined by age-, gender- and height-specific references**

Gender	Area under curve	p-value*	95% CI
<b>Boys</b>			
SBP $>90^{\text{th}}$ and $<95^{\text{th}}$	0.924	0.000	0.897-0.950
DBP $>90^{\text{th}}$ and $<95^{\text{th}}$	0.916	0.000	0.887-0.944
SBP $\geq 95^{\text{th}}$	0.991	0.000	0.983-0.998
DBP $\geq 95^{\text{th}}$	0.988	0.000	0.979-0.997
SBP $>99^{\text{th}}$ +5mm Hg	0.989	0.003	0.977-1.000
DBP $>99^{\text{th}}$ +5mm Hg	0.988	0.004	0.977-0.999
<b>Girls</b>			
SBP $>90^{\text{th}}$ and $<95^{\text{th}}$	0.903	0.000	0.863-0.943
DBP $>90^{\text{th}}$ and $<95^{\text{th}}$	0.922	0.000	0.893-0.950
SBP $\geq 95^{\text{th}}$	0.981	0.000	0.967-0.995
DBP $\geq 95^{\text{th}}$	0.995	0.000	0.989-1.000
SBP $>99^{\text{th}}$ +5mm Hg	0.995	0.016	0.985-1.000
DBP $>99^{\text{th}}$ +5mm Hg	0.998	0.015	0.993-1.000

DBP, diastolic blood pressure; DBPHR, diastolic blood pressure-to-height ratio; ROC, receiver-operating characteristic; SBP, systolic blood pressure; SBPHR, systolic blood pressure-to-height ratio. \* $p < 0.001$ .

The optimal cut-off points were determined based on ROC curve analysis when the sum of sensitivity and specificity reached a maximum. PPV and NPV were calculated using Baye's theorem. The negative predictive values were much higher (all  $>99\%$ ) for prehypertension and hypertension, although the positive predictive values were relatively lower, ranging from 10% to 75%. (**Table 2**)

**Table 2: Optimal cut-off points of SBPHR and DBPHR as well as corresponding sensitivity and specificity among adolescents.**

	SBP $>90^{\text{th}}$ and $<95^{\text{th}}$		SBP $\geq 95^{\text{th}}$		SBP $>99^{\text{th}}$ + 5 mmHg	
	Boys (75)	Girls (56)	Boys (30)	Girls (20)	Boys (3)	Girls (2)
Cut-off points	0.725	0.745	0.765	0.795	0.825	0.865
Sensitivity	0.987	0.946	0.97	0.955	1.000	1.000
Specificity	0.895	0.915	0.959	0.932	0.974	0.987
PPV	0.560	0.644	0.543	0.463	0.103	0.133
NPV	0.998	0.990	0.999	0.997	1.000	1.000
	DBP $>90^{\text{th}}$ and $<95^{\text{th}}$		DBP $\geq 95^{\text{th}}$		DBP $>99^{\text{th}}$ + 5 mmHg	
	Boys (75)	Girls (56)	Boys (30)	Girls (20)	Boys (3)	Girls (2)
Cut-off points	0.465	0.465	0.495	0.515	0.525	0.585
Sensitivity	0.947	1.000	0.939	1.000	1.000	1.000
Specificity	0.916	0.906	0.978	0.98	0.974	0.992
PPV	0.605	0.633	0.682	0.754	0.103	0.200
NPV	0.992	1.000	0.996	1.000	1.000	1.000

DBP, diastolic blood pressure; DBPHR, diastolic blood pressure-to-height ratio; SBP, systolic blood pressure; SBPHR, systolic blood pressure-to-height ratio; PPV, positive predictive value; NPV, the negative predictive value

As seen in table 2, optimal threshold values were used to define hypertension (stages 1 and 2) and prehypertension. Hypertension was defined by SBPHR of  $\geq 0.765$  and/or DBPHR of  $\geq 0.495$  in boys, and SBPHR of  $\geq 0.795$  and/or DBPHR of  $\geq 0.515$  in girls. Hypertension (stage 2) was defined by SBPHR of  $\geq 0.825$  and/or DBPHR of  $\geq 0.525$  in boys and by SBPHR of  $\geq 0.865$  and/or DBPHR of  $\geq 0.585$  in girls. Prehypertension was defined by SBPHR of  $\geq 0.725$  and/or DBPHR of  $\geq 0.465$  in boys and SBPHR of  $\geq 0.745$  and/or DBPHR of  $\geq 0.465$  in girls.

SBPHR and mean SBP are positively correlated ( $r = 0.697$ ;  $p < 0.001$ ). Similarly DBPHR and DBP are positively correlated ( $r = 0.705$ ;  $p < 0.001$ ) indicating a good linear relationship.

In boys, the correlation between SBPHR and age ( $r = -0.048$ ,  $p = 0.231$ ) was negative, that is inverse correlation. Similarly, the correlation between SBPHR and height ( $r = -0.069$ ,  $p = 0.083$ ); DBPHR and age ( $r = -0.083$ ,  $p = 0.039$ ); DBPHR and height ( $r = -0.112$ ,  $p = 0.005$ ) was also negative.

In girls, the correlation between SBPHR and age ( $r = 0.065$ ,  $p = 0.211$ ) was very weakly correlated, indicating little or no linear relationship. The correlation between SBPHR and height ( $r = -0.054$ ,  $p = 0.293$ ) was negative. The correlation between DBPHR and age ( $r = 0.095$ ,  $p = 0.066$ ) was weakly correlated as well, the correlation between DBPHR and height ( $r = -0.021$ ,  $p = 0.681$ ) was negative.

In Boys, mean BMI in hypertensive males is 24.08; and mean BMI in prehypertensive males is 23.56, which was significantly higher than the rest of students at 17.74. There is a significant difference in the t-test for equality for means ( $p < 0.001$ ) indicating that higher BMI is significantly associated with hypertensive males.

### Discussion:

BPHR is strongly and positively associated with systolic and diastolic blood pressure, but is not dependent on height or age, as shown in our study. The blood pressure to height ratios (SBPHR and DBPHR) both considers the height of the adolescent subject. The inverse correlation between both, SBPHR, DBPHR, and height implies that shorter subjects had relatively higher values while taller subjects had relatively smaller values, therefore ensuring that tall adolescents (who have normal weights) are not misclassified as hypertensives or short and heavy adolescents are not misclassified as normotensives. Such misclassification was observed when a single age-specific blood pressure value was used.

The area under the ROC curves found in this study shows that SBPHR and DBPHR have robust discriminatory capacities for diagnosing hypertension (in this population). All AUCs were  $> 0.9$  in both sexes (ranging from 0.916-0.998) and  $p$ -value  $< 0.05$  making this test both accurate and significant. In the study by Ejike of children aged 11-17 years, the AUC values for the accuracy of both SBPHR and DBPHR in diagnosing both prehypertension and hypertension in both sexes ranged from 0.925 to 1.000.<sup>[1]</sup> The study by Lu done on children aged 13-17 years, shows that for both genders, the accuracy levels of SBPHR and DBPHR for identifying elevated SBP and DBP (as assessed by AUC) were both  $> 0.85$  (0.989-1.000).<sup>[2]</sup> In the study done by Xiaofan et al, All AUC's were  $> 0.9$  in both sexes in adolescents aged 13-18 yrs except for those identifying the level of SBP between the 90th and 95th percentiles in which also it was  $> 0.85$ .<sup>[3]</sup> In a study by Ahmed et al, all AUC's ranged between 0.84- 0.94.<sup>[4]</sup>

In our study, optimal threshold values are as shown above in the result. The sensitivity and specificity in all cases were above 88%. In other studies, as done by Ejike, Lu, Xiaofan, Ahmed, there were mild differences in the optimal thresholds for prehypertension and hypertension in both boys and girls.<sup>[1-4]</sup> The variations could be as a result of differences in race/ genetics or differences in socioeconomic and cultural factors. The observed differences in threshold values may only suggest that race-specific reference values are required.

The high negative predictive value of  $> 99\%$  in our study shows that children with hypertension and prehypertension are unlikely to be missed by these cut-offs. However, the positive predictive value (PPV) is low (10-75) suggesting that some children with normal BP may be classified as prehypertensive or hypertensive. PPV is directly proportional to the prevalence of the disease. As the prevalence of hypertension is low in children, therefore PPV remained low in our study as in other studies. In the study done by Xi, the negative predictive values were much higher (all  $> 99\%$ ) for prehypertension and hypertension, although the positive predictive values were relatively lower, ranging from 13% to 75%.<sup>[5]</sup> In the study done by Ahmed, NPV was  $> 99\%$  in both prehypertensives and hypertensives, PPV varied from 29-85%,<sup>[4]</sup> thus corroborating the findings in our study. In our study, higher BMI was significantly associated with prehypertensive and hypertensive populations in both males ( $p < 0.001$ ) and females ( $p < 0.001$ ). In the study done by Lu, BMI was strongly associated with the risk for hypertension, in multivariate logistic regression, the prevalence of hypertension among overweight (12.0%) and obese (25.9%) adolescents was 4.043 (2.763-5.915) times and 11.423 (7.843-16.637) times that of normal-weight adolescents (3.6%), respectively, after adjustment for age and gender ( $P < 0.01$ ).<sup>[2]</sup> In the study done by Galescu, the proportion of overweight girls and boys with BP reading above 90th

percentile was 11% and 10% respectively. The proportion of BP above 90th percentile in all girls and boys was 6.3% and 5.2%, respectively, indicating that higher BMI is associated with increased risk of hypertension and prehypertension (HTPHT).<sup>[6]</sup>

In our study, positive family history was associated *only* with hypertensive boys ( $p < 0.001$ ), in every other demographic, positive family history was not significantly associated with HTPHT ( $p > 0.05$ ). In the study by Priyanga, in adults, the prevalence of hypertension was significantly higher in patients with an FH (29.3 %,  $n=572/1951$ ) than those without (24.4 %,  $n=616/2530$ ) ( $p < 0.001$ ).<sup>[7]</sup>

### Between Two Schools

The first school was a private school (affluent class) and the second school was a government school (middle class). We wanted to see whether there is a significant difference in the prevalence of hypertension (HT) and prehypertension (PHT) amongst both schools.

There was a significant difference only in Hypertensive males between the two schools ( $p < 0.05$ ) (odds ratio = 2.4) ie. The school I males are 2.4 times more likely to have hypertension in comparison to school II males. This may be due to more pocket money being available to school I and to boys, who indulge in more junk food eating; however, we did not analyze this.

There was no significant difference in any other group between PHT males in school I and school II; between HT females in school I and school II; between PHT females in school I and school II).

**Strength of study:** It is the first study in the Gujarat state of the Indian subcontinent independent of the economic condition of the students as both private and government schools were selected.

**Limitations of the study:** The not-too-large sample size indicates a reduced statistical power of the entire analyses.

### Conclusion:

BP/height ratio is a simple, excellent screening and diagnostic tool with high sensitivity and of children.<sup>[8]</sup> The BP/height ratios also correlated with the corresponding BP percentiles in both genders. It *reduces drastically* the number of threshold values that are needed in diagnosing hypertension in adolescents.

It would, therefore, be easily appreciated by non-medical professionals, especially adolescents, and medical professionals alike. It may also eliminate the under-diagnosis of adolescent HTPHT, and in turn, help in the early management of and reduction in the morbidity and mortality arising from its sequel. Higher BMI is associated with increased cases of HTPHT. Family history was significant only in hypertensive boys in our study.

### Recommendation:

1. Blood pressure to height ratios can be used successfully in the screening of hypertension and prehypertension in both boys and girls.
2. Boys and girls with higher BMI, and boys with family history, should be watched out for hypertension and prehypertension.

### What is already known:

BP/height ratio is a simple and useful tool for screening hypertension and prehypertension, however, it requires validation in different racial groups to be able to be used worldwide.

### What this study adds:

It is the first study from Gujarat state of India, independent of the economic condition of the students as both private and government school was selected.

It remains a useful and accurate tool for screening hypertension and prehypertension.

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