Section: Paediatrics

Original Research Article

# HARNESSING BP/HEIGHT RATIO FOR PRECISE SCREENING OF PRE-HYPERTENSION AND HYPERTENSION IN CHILDREN

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## Abstract

This research endeavours to evaluate the utility of the Blood Pressure (BP) to Height Ratio as a robust screening tool for the identification of pre-hypertension and hypertension in children. Spanning a diverse demographic of urban and rural school children in Madurai, the study employs a cross-sectional design over six months. The primary objective is to establish threshold values for the BP/Height Ratio and explore its correlation with conventional blood pressure percentiles. The study adheres to rigorous ethical considerations and delineates comprehensive methodologies, aiming to contribute valuable insights for the development of effective screening practices in paediatric hypertension detection. The results showed that the prevalence of pre-hypertension was 4.7% and hypertension was 3.9% according to BP centile chart, and prevalence of pre-hypertension was 9.2% and hypertension was 6.8% according to BP/HTR. BPHTR is highly sensitive (86%) and specific (95%) screening tool for the diagnosis of pre-hypertension and hypertension. Good correlation was found to exist between BP centile and BPHTR with $p<0.0001$.

## INTRODUCTION

In the realm of public health, understanding and monitoring blood pressure (BP) in children have become increasingly pivotal. Recognized as a global health concern, hypertension not only affects adults but also establishes its roots in childhood. This early onset emphasizes the importance of proactive measures in tracking and interpreting blood pressure levels among the younger demographic.[1] Tracking blood pressure (BP) from an early age is essential, as both hypertension and pre-hypertension can adversely affect vital organ function. Current practices, as outlined in the 'National High Blood Pressure Education Program Working Group's' fourth report, emphasize BP documentation for children above the age of three during health clinic visits.[2] However, interpreting paediatric BP levels accurately is time-consuming and challenging due to the need for adjustments based on age, gender, and height.[3]

**Need for Simplified Indices**

To improve the identification of hypertensive cases among children, the use of simple indices like SBP-to-height ratio (SBPHR) and DBP-to-height ratios (DBPHR) has gained traction, globally.[4] These indices offer a more straightforward interpretation of BP levels in the paediatric population. While healthcare systems primarily focus on identifying and addressing hypertension in adults, the rising prevalence of pre-hypertension and hypertension in children and adolescents necessitates a paradigm shift.[5-7] Our study aims to underscore the significance of vigilance in monitoring blood pressure in children, emphasizing the need for accessible and efficient methods. As we delve into this exploration, we recognize the value of identifying thresholds and simplifying interpretation through innovative indices, paving the way for early intervention and improved health outcomes in the paediatric population

**Aims & Objective**

1. To identify a threshold value for detecting pre-hypertension & hypertension using BP/Height ratio for both systolic BP and diastolic BP among children aged between 6 and 15 years in urban and rural schools in Madurai.

To study the relationship between BP/height ratios and corresponding BP percentiles in children.

## MATERIALS AND METHODS

**Study Setting:** The study was conducted in both urban and rural schools in Madurai.

**Study Design:** A cross-sectional study design was employed.


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**Study Population**: The study included children aged 6-15 years attending schools. A total of 1568 school children, with 779 children from urban schools and 789 from rural schools participated in our study.

**Sample Size Calculation:** The expected prevalence of hypertension or prehypertension: based on previous research was around 20%(8). Desired level of precision with a margin of error (precision) of ±2% and 95% confidence level, using the formula,

$n=Z^2\times p\times (1-p)/E^2$

$n= 1.96^2 \times 0.20\times (1-0.20)/0.02^2= 1536$

we conclude that we require a sample size with 1536 children in our study to achieve the desired level of precision and confidence in estimating the prevalence of hypertension or prehypertension. We have included 1568 school children in our study.

**Sampling Methods**: we obtained a comprehensive list of all schools within the study area that cater to children aged 6-15 years. We then stratified the sampling frame into two strata: urban schools and rural schools to ensure representation from both settings. Finally, we included 779 children from urban schools and 789 from rural schools in our study.

**Data Collection Methods**: The data was collected using a predesigned and pretested questionnaire. The demographic data along with the clinical history were collected. The height, weight, Blood pressure, and Body mass index were measured as follows:

1. **Measurement of Height:** For each subject, the height was measured to the nearest of 0.5 cm, using a non-elastic measuring tape, fastened to a vertical wall. The subjects were asked to stand on bare feet during the measurement. Height percentile is determined by using newly revised CDC Growth Charts.[9]
2. **Measurement of weight:** The subjects were weighed electronic weighing balance scale with bare feet and light clothing. The weight was measured to the nearest 0.1 kg.
3. **Body Mass Index (BMI):** Using values from the weight and height measurements, Body Mass Index (BMI) was calculated using the formula BMI = Weight (kg)/ [Height (m)]$^2$.
4. **Blood pressure (BP) measurement:** The BP was measured after five minutes of rest in the seated position with the right arm supported at heart level. A Mercury manometer was used for measuring the BP. Systolic Blood pressure (SBP) and Diastolic Blood Pressure (DBP) were noted based on the onset of the "tapping" Korotkoff sounds and disappearance of Korotkoff sounds respectively. NHANES charts are used for analysing BP.(10) For children whose BP was above 90th centile BP was repeated twice at 5-10 minute intervals in the same visit and average BP was recorded. BP consistently between 90-95th centile were considered pre-hypertensives. For children whose BP was above the 95th centile BP was repeated at weekly intervals and BP consistently above the 95th centile was considered as hypertensives. BP/HTR were calculated for all children for both systolic and diastolic values. Similarly, pre-hypertension and hypertension systolic and diastolic thresholds were calculated for pre-hypertension and hypertension.

**Inclusion Criteria**: All healthy school children aged 6-15 years were included in the study.

**Exclusion Criteria:** Children showing signs of ill-health upon examination or those on medication for any diseases were excluded.

**Data Entry And Analysis:** Data were entered into SPSS 16 software for tabulation and analysis. Correlation analysis was conducted using the Pearson correlation coefficient.

**Ethical Considerations**: Ethical approval was obtained from the Institutional Ethical Committee. Additionally, approvals were secured from the principals of the participating schools.

## RESULTS

Our study encompassed a cohort of 1568 students, with 779 (49.7%) attending urban schools and 789 (50.3%) from rural schools. Gender distribution revealed 752 (48%) male students and 816 (52%) female students. Among them, 334 (21.3%) fell within the 6-9 age group, 517 (33%) within the 10-12 age group, and 717 (45.7%) within the 13-15 age group.

Regarding blood pressure (BP) measurements, systolic BP fell below the 50th percentile for 678 (43.2%) students, between the 51-90th percentile for 756 (48.2%) students, between the 91-95th percentile for 73 (4.7%) students and exceeded the 95th percentile for 61 (3.9%) students. Similarly, diastolic BP was below the 50th percentile for 655 (41.8%) students, between the 51-90th percentile for 833 (53.1%) students, between the 91-95th percentile for 68 (4.3%) students and exceeded the 95th percentile for 12 (0.8%) students.

The prevalence of pre-hypertension was 4.5% in urban areas, 4.8% in rural areas, and 4.7% overall. Hypertension prevalence stood at 4% in urban areas, 3.8% in rural areas, and 3.9% overall.

**Prevalence among different age groups:**

Across the age-groups the prevalence of pre-hypertension was 1.8% between 6-9 years, 5.6% between 10-12 years and 5.3% between 13-15 years. Also, the prevalence of hypertension was 0 % between 6-9 years, 3.7% between 10-12 years and 5.9% between 13-15 years. Pre-hypertension and hypertension were more prevalent in more than 10 years of age which is statistically significant.

**Prevalence based on gender:**

Prevalence of pre-hypertension among boys was 5.6 % and among girls was 3.8 %. Prevalence of hypertension among the boys was 4% and girls was 3.8%. Prevalence of diastolic pre-hypertension among boys was 4.8% and among girls was 3.9%. The prevalence of hypertension among the boys was 0.7% and girls were 0.9%. the difference between the genders was not significant.


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**Family History and Hypertension**

Out of 1568 children, 172 (11%) have a definite family history of hypertension. Among those 172 students with a definite family history of hypertension, 7.6% have pre-hypertension and 9.9% have hypertension compared to those without a family history of hypertension in which only 4.3% were pre-hypertensive and 3.2% were hypertensive. There was a significant association between the family history of hypertension and hypertension which is statistically significant.

**BMI Percentile and Hypertension**

Out of 1568, 43(2.7%) were overweight and 41(2.6%) were obese. Prevalence of overweight was 2.7%. Among 2.7%, 11.6% were in pre-hypertension range and 18.6% are in hypertension range.

Prevalence of obesity is 3.1%. Among obese 20% were in pre-hypertension range and 26% were in hypertension range. High prevalence of pre-hypertension and hypertension among overweight and obese children compared to normal children has a strong statistical significance.

The prevalence of pre-hypertension among boys was 2.7% and among girls was 2%, while hypertension prevalence was 1.9% among boys and 2% among girls.

**Diastolic BP Centile and Gender**

Diastolic pre-hypertension prevalence was 4.8% among boys and 3.9% among girls, with hypertension prevalence at 0.7% among boys and 0.9% among girls. The difference between the gender is not statistically significant.

**Prevalence of diastolic pre-hypertension among different age groups**:

Diastolic blood pressure of all pre-hypertensives, 1% was between the 6-9 years of age group and 3.2% was between the 10-12 years of age group and 6% was between the 13-15 years age group. Of all hypertensives, 0.8% were between 10-12 years of age group and 1.1% were between 13-15 years of age group. Pre-hypertension and hypertension are more prevalent in more than 10 years of age. The difference between each age group is statistically significant.

**Mean Blood Pressure**

The mean systolic BP in boys was 101.92 and in girls was 102.28. The mean diastolic BP in boys was 64.32 and in girls was 65.65.

The mean SBPHTR (systolic blood pressure hypertension ratio) in boys was 0.73 and in girls was 0.74. The mean DBPHTR (diastolic blood pressure hypertension ratio) in boys was 0.46 and in girls was 0.47.

**Table 1: Anthropometric and Blood pressure parameters of the study participants**

| | | N | Mean | Std. Deviation | 95% Confidence Interval for Mean | |
|---|---|---|---|---|---|---|
| Characteristics | | | | | Lower Bound | Upper Bound |
| HEIGHT | 1 (6 TO 9) | 334 | 117.2485 | 8.67677 | 116.3146 | 118.1824 |
| | 2 (10 TO 12) | 517 | 138.1122 | 9.61784 | 137.2812 | 138.9432 |
| | 3 (13 -15) | 717 | 149.7755 | 10.85550 | 148.9795 | 150.5714 |
| | Total | 1568 | 139.0013 | 15.95423 | 138.2110 | 139.7916 |
| HT CENTILE | 1 (6 TO 9) | 334 | 17.3503 | 17.23186 | 15.4955 | 19.2051 |
| | 2 (10 TO 12) | 517 | 24.6325 | 24.40494 | 22.5239 | 26.7411 |
| | 3 (13 -15) | 717 | 20.3766 | 22.34344 | 18.7383 | 22.0148 |
| | Total | 1568 | 21.1352 | 22.24163 | 20.0335 | 22.2369 |
| WEIGHT | 1 (6 TO 9) | 334 | 18.7246 | 3.78263 | 18.3174 | 19.1317 |
| | 2 (10 TO 12) | 517 | 31.8928 | 8.24498 | 31.1805 | 32.6052 |
| | 3 (13 -15) | 717 | 41.1252 | 9.41877 | 40.4347 | 41.8158 |
| | Total | 1568 | 33.3096 | 11.82854 | 32.7236 | 33.8955 |
| Sys BP | 1 (6 TO 9) | 334 | 91.9072 | 8.62814 | 90.9785 | 92.8359 |
| | 2 (10 TO 12) | 517 | 101.6480 | 10.50673 | 100.7402 | 102.5558 |
| | 3 (13 -15) | 717 | 107.2008 | 10.59205 | 106.4242 | 107.9774 |
| | Total | 1568 | 102.1122 | 11.72821 | 101.5313 | 102.6932 |
| Dias BP | 1 (6 TO 9) | 334 | 59.0359 | 7.81574 | 58.1947 | 59.8772 |
| | 2 (10 TO 12) | 517 | 64.9226 | 6.90956 | 64.3256 | 65.5196 |
| | 3 (13 -15) | 717 | 67.8675 | 6.76072 | 67.3718 | 68.3632 |
| | Total | 1568 | 65.0153 | 7.80594 | 64.6286 | 65.4020 |
| S BP HT RATIO | 1 (6 TO 9) | 334 | .7852 | .07186 | .7775 | .7929 |
| | 2 (10 TO 12) | 517 | .7375 | .07445 | .7311 | .7439 |
| | 3 (13 -15) | 717 | .7166 | .07972 | .7107 | .7224 |
| | Total | 1568 | .7381 | .08069 | .7341 | .7421 |
| DIAS BP HT RATIO | 1 (6 TO 9) | 334 | .5026 | .06518 | .4956 | .5096 |
| | 2 (10 TO 12) | 517 | .4721 | .05991 | .4670 | .4773 |
| | 3 (13 -15) | 717 | .4558 | .05790 | .4515 | .4600 |
| | Total | 1568 | .4711 | .06274 | .4680 | .4742 |
| BMI | 1 (6 TO 9) | 334 | 13.5573 | 1.82265 | 13.3611 | 13.7535 |
| | 2 (10 TO 12) | 517 | 16.6131 | 3.52852 | 16.3082 | 16.9179 |
| | 3 (13 -15) | 717 | 18.2867 | 3.37945 | 18.0389 | 18.5345 |
| | Total | 1568 | 16.7275 | 3.64459 | 16.5469 | 16.9080 |


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As age increases systolic, and diastolic BP, weight and BMI increase ($r=0.75$, $p<0.05$). But BPHTR has no correlation with age ($r=0.436$, $p<0.05$).

BPHTR (Blood pressure hypertension ratio):

The optimum threshold value for pre-hypertension and hypertension in our study group was determined by checking from a range of possible cut-off points that had sensitivity and specificity that yielded the maximum from the ROC (Receiver Operating characteristic) curves.

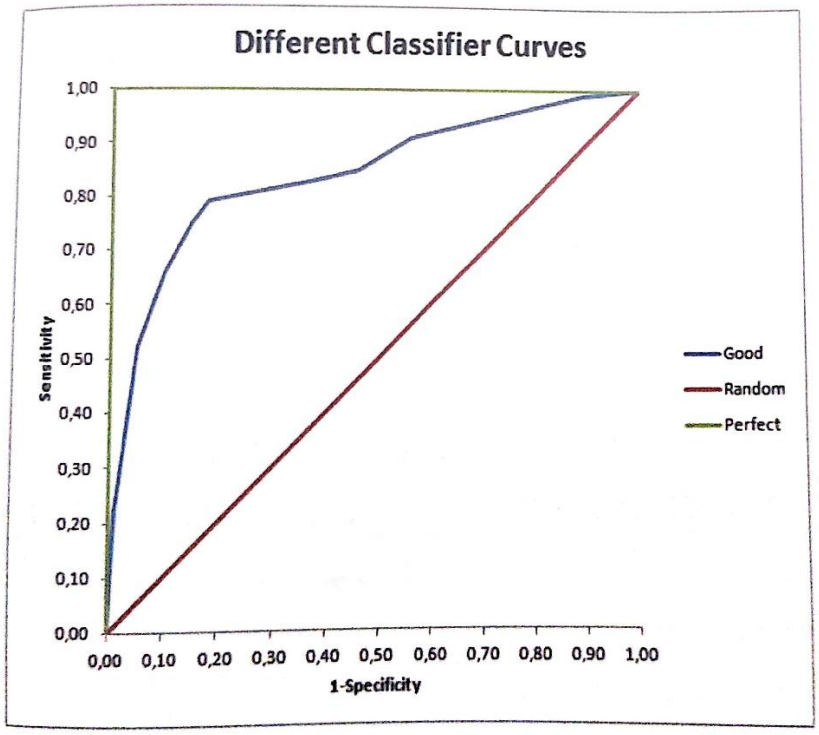


**Figure 1: ROC Curve**

The identified threshold for pre-hypertension and hypertension in our study group was,

Pre-hypertension:

BPHTR for Boys - Systolic-0.79 and Diastolic-0.49. The BPHTR for Girls - Systolic-0.78 and Diastolic-0.49

Hypertension:

BPHTR for Boys - Systolic-0.82 and Diastolic-0.60. The BPHTR for Girls - Systolic-0.81 and Diastolic-0.60

The prevalence of systolic pre-hypertension among the boys was 12%, and systolic hypertension was 8%. The prevalence of systolic pre-hypertension among the girls was 6.5%, and systolic hypertension was 6%. The prevalence of diastolic pre-hypertension among the boys was 12.7%, and systolic hypertension was 3.3%. The prevalence of diastolic pre-hypertension among girls was 12.5%, and systolic hypertension was 2.9%. The overall prevalence of systolic pre-hypertension was 9.2% and hypertension was 6.8%. The overall prevalence of diastolic pre-hypertension was 12.6% and hypertension was 2.9%.

**Prevalence among boys of different age groups:**

Pre-hypertension in 6-9 years was 2.1%, 10-12 years was 4.2% and 13-15 years was 4.8%. Hypertension in 6-9 years was 1%, 10-12 years was 3.4% and 13-15 years was 4.8%.

**Prevalence among girls of different age groups:**

Pre-hypertension in 6-9 years was 1.3%, 10-12 years was 2.4% and 13-15 years was 3.6%. Hypertension in 6-9 years was 0.6%, 10-12 years was 3.5% and 13-15 years was 3.1%.

Pre-hypertension and hypertension were common in >10 years of age which was statistically significant.

Using the cut-off points as a diagnostic tool for normotension, prehypertension, and hypertension, the sensitivity and specificity of the thresholds were calculated.

**Table 2: Cut off points for Prehypertension and Hypertension in both Girls and Boys**

| | SBPHTR | | DBPHTR | |
|---|---|---|---|---|
| **GENDER** | **BOYS** | **GIRLS** | **BOYS** | **GIRLS** |
| **PREHYPERTENSION** | | | | |
| **THRESHOLD** | 0.79 | 0.78 | 0.49 | 0.49 |
| **SENSITIVITY** | 88% | 84% | 83% | 84% |
| **SPECIFICITY** | 92% | 96% | 93% | 90% |


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| HYPERTENSION | | | | |
|---|---|---|---|---|
| **THRESHOLD** | 0.82 | 0.81 | 0.6 | 0.6 |
| **SENSITIVITY** | 93% | 93% | 80% | 85% |
| **SPECIFICITY** | 95% | 97% | 97% | 98% |

SYS BPHTR in boys for prehypertension has a sensitivity of 88% and a specificity of 92%.
SYS BPHTR in girls for prehypertension has a sensitivity of 84% and specificity of 96%
DIAS BPHTR in boys for prehypertension has a sensitivity of 83% and specificity of 93%
DIAS BPHTR in girls for prehypertension has a sensitivity of 84% and specificity of 90%
SYS BPHTR in boys for hypertension has a sensitivity of 93% and specificity of 95%
SYS BPHTR in girls for hypertension has a sensitivity of 93% and specificity of 97%
DIAS BPHTR in boys for hypertension has a sensitivity of 80% and specificity of 97%
DIAS BPHTR in girls for hypertension has a sensitivity of 85% and specificity of 98%.

**Table 3: Correlation between BP percentile and BPHTR**

| TEST | MALE | | FEMALE | |
|---|---|---|---|---|
| | SBP Centile Vs SBP HT Ratio | DBP Centile Vs DBP HT Ratio | SBP Centile Vs SBP HT Ratio | DBP Centile Vs DBP HT Ratio |
| Correlation | .434(**) | .587(**) | 0.531 | 0.207 |
| p Value | .000 | .000 | .000 | .000 |
| Significant Level | Significant | Significant | Significant | Significant |

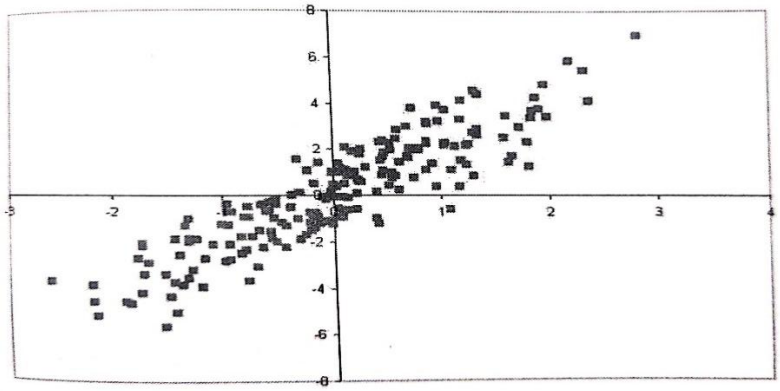


**Figure 2: Scatter plot between BP Percentile and BPHTR**

BPHTR has a very good correlation with BP centile charts, and it has a high statistical significance of p=<0.0001, correlation coefficient r=0.86.

**Table 4: Correlation between BP centile, BPTHR with different variables**

| | AGE | HEIGHT | WEIGHT | BMI |
|---|---|---|---|---|
| **SBPHT** | 0.072(O.093) | 0.011(<0.001) | 0.092(0.060) | 0.186(<0.001) |
| **DBPHT** | 0.052(0.073) | 0.192(<0.001) | 0.019(.690) | 0.121(<0.001) |
| **SBP** | O.320(<0.001) | 0.324(<0.001) | 0.292(<0.001) | 0.152(<0.001) |
| **DBP** | 0.212(<0.001) | 0.123(<0.001) | 0.152(<0.001) | 0.124(<0.001) |

BPHTR has a very good correlation with BP centile, height, and BMI but has no correlation with age and weight. It has a high statistical significance with p=<0.0001 and r=0.72.

## DISCUSSION

Threshold value for pre-hypertension and hypertension

**Pre-Hypertension**

BPHTR for boys was systolic-0.79 and diastolic was 0.48. similarly, BPHTR for girls was systolic-0.79 and diastolic-0.49.

**Hypertension**

BPHTR for boys was systolic-0.82 and diastolic-0.6. Similarly, BPHTR for girls was systolic-0.81 and diastolic-0.6

It has the very good sensitivity and specificity between 83-99%

Similar study published by Lu et al who first identified the threshold value using this formula in 2011 in 13-15 years old adolescents.[11] The thresholds identified for pre-hypertension for boys were 0.75/0.48, for girls 0.78/0.51, similarly for hypertension, it was 0.81/0.57 for boys, 0.84/0.63 for girls and it has a significant correlation with BP centile.

Another study done in Italy by Chukwunonso ECC Ejike et al in 2011[12] identified the thresholds for pre-hypertension for boys were 0.72/0.46, and for girls


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0.73/0.48, similarly for hypertension, it was 0.75/0.51 for boys,0.77/0.50 for girls.
So far, no studies were done in Indian population.

**BPHTR and BP Centile**

BPHTR has a very good correlation with BP centile, height and BMI but has no correlation with age and weight. It has a high statistical significance in this study with p=<0.0001. The results are similar to study done in New York in 2012 by Ovidiu et al that BPHTR has a strong significant correlation with corresponding BP centile in children.[13]

**Prevalence of Hypertension**

In this cross sectional study on 1568 apparently healthy school children between 6-15 year age group, the prevalence of pre-hypertension was 4.7% (n=73) and hypertension was 3.9% (n=61) according to BP centile chart and 9.2% and 6.8% according to BP/HTR .This is similar to Indian study which showed that the prevalence of hypertension between 11-17 years according to BP percentile chart was 5.19%.[14] Another similar study by Roya Kelishadi et al done in Iran, published in Journal of Paediatrics 2013 showed that the prevalence of pre hypertension and hypertension according to BPHTR were 6.9% and 5.6% respectively.[15]

**Association of Age and Blood Pressure**

Incidence of pre-hypertension in 5-9 year 1.8%,10-12-year age group was 5.6% and in 13-15 years was 5.3%. Incidence of hypertension in 5-9 year was 0%, 10-12-year age group was 3.7% and in 13-15 years was 5.9%.

In our study most of the hypertensive cases were above 13 years. It is similar to the sun S study, where the HT prevalence was high among 12-15 years.[16]

BP had a good correlation with age, but BPHTR had no significant correlation with age in this study which was statistically significant p= (<0.001). Similar study done in Italy by Chukwunonso et al in 2011 using BPHTR also documented that BPHTR has no correlation with age. So, BPHTR is not age dependent.[12]

**Family History**

Among those 172 with definite family history of hypertension ,7.6% had pre-hypertension and 9.9% had hypertension as compared to those without family history among whom, only 4.3% had pre-hypertension and 3.2% had hypertension. So, family history is a definite risk factor for hypertension, which is statistically significant (p<0.05).

**BMI**

Prevalence of overweight was 2.7% and obesity was 3.1% in our study. Among overweight 11.6% were in the pre- hypertension range and 18.6% were in the hypertension range, among obese 20% were in the pre- hypertension range and 26% were in the hypertension range when compared to normal weight children who have only 4.1% pre- hypertension and 3.1% hypertension. It's similar to an article published by Pamela A. Dyson et al in 2013 which states overweight children has 1.7-2.3 times increased risk of hypertension and obese has 3.5-5 times increased risk of hypertension.[5] BPHTR also had good correlation with BMI in this study (p=<0.05). Similar study done in Italy in 2011 also had good correlation between BPHTR and BMI.

## CONCLUSION

1.The prevalence of pre-hypertension was 4.7% and hypertension was 3.9% according to BP centile chart, and prevalence of pre-hypertension was 9.2% and hypertension was 6.8% according to BP/HTR.

2.Cutoff of BP/HTR: In pre-hypertension, BPHTR for boys showed systolic as 0.79 and diastolic as 0.48. The BPHTR for girls showed systolic as 0.79 and diastolic as 0.49. For hypertension, BPHTR for boys showed systolic as 0.82 and diastolic as 0.6. The BPHTR for Girls showed systolic as 0.81and diastolic as 0.6.

3.BPHTR is highly sensitive (86%) and specific (95%) screening tool for the diagnosis of pre-hypertension and hypertension. Good correlation was found to exist between BP centile and BPHTR with p<0.0001.

5. More number of hypertensives can be identified by using this simple threshold value.

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**Competing Interest**

There is no competing interest

**Authors Contribution**

All authors in our study contributed to the data collection of the patients

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