RESEARCH PAPER

# Blood Pressure Distribution and Anthropometric Correlates among Children Aged 8-16 Years in Urban Private Schools of Bangalore: A Cross-Sectional Study

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**ABSTRACT**

**Introduction:** Elevated blood pressure in childhood may track into adulthood, but population-specific evidence among Indian schoolchildren remains limited. This study determined blood pressure distribution and examined associations with sex and anthropometric measures among children attending urban private schools in Bangalore.

**Methods:** This cross-sectional study included 1,289 children aged 8-16 years selected by stratified random sampling between June 2012 and March 2014. Height, weight, BMI-for-age, and auscultatory blood pressure were measured using standardized procedures. Blood pressure was classified using age-, sex-, and height-specific Fourth Report percentiles. Associations were assessed using chi-square or Fisher exact tests and correlation coefficients.

**Results:** Among 1,289 participants, 580 (45.0%) were boys and 709 (55.0%) were girls. Systolic prehypertension and hypertension occurred in 37 (2.9%) and 62 (4.8%) children; diastolic prehypertension and hypertension occurred in 92 (7.1%) and 131 (10.2%). Overall hypertension prevalence was 10.7% (138/1,289). Systolic and diastolic hypertension were more frequent among girls than boys (7.8% vs 1.2%, $P = 1.57 \times 10^{-11}$; 12.7% vs 7.1%, $P = 0.000806$). Age, height, and weight correlated positively with systolic and diastolic pressure in both sexes (r = 0.18-0.59). Obesity (> +2 SD) was present in 64 (5.0%) children and was associated with systolic hypertension (18.8% vs 4.1%, $P = 0.0000245$) and diastolic hypertension (25.0% vs 9.4%, $P = 0.000362$).

**Conclusion:** Elevated blood pressure was common, particularly diastolic hypertension, and was associated with sex, age, body size, and obesity. Standardized blood pressure and anthropometric assessment in school health services may help identify children who require follow-up.

**Keywords:** Anthropometry; blood pressure; children; hypertension; obesity; school health

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## INTRODUCTION

Elevated blood pressure (BP) in childhood is clinically important because BP tracks from childhood into adulthood and the origins of essential hypertension can be detected early.[1] Interpretation of pediatric BP requires age-, sex-, and height-specific reference limits.[2] Indian studies have established population-specific BP distributions, but reported hypertension prevalence varies substantially across settings because of differences in age range, measurement protocol, diagnostic criteria, and adiposity.[3-6] Local evidence is therefore important for screening strategies. This study determined BP distribution among 8-16-year-old children in urban private schools of Bangalore and examined associations with sex, age, height, weight, and body mass index (BMI).

## MATERIALS AND METHODS

### Study Design and Participants

This cross-sectional observational study was conducted from June 2012 through March 2014 in urban private schools in Bangalore selected by stratified random sampling. Children aged 8-16 years attending the selected schools were eligible. Children with a chronic systemic disease, those absent during data collection, and those unwilling to participate were excluded. The protocol specified a target of 1,000 participants using n = $Z^2pq/d^2$ (Z = 1.96, anticipated hypertension prevalence = 5%-10%, and absolute precision = 2%), with provision to extend recruitment.[7]

### Measurements

Age was verified from school records. Height was measured barefoot with the child upright, heels, buttocks, and shoulders against the wall, and head in the Frankfurt plane, using a sliding stadiometer. Weight was recorded on a calibrated spring balance to the nearest 0.5 kg. BMI was calculated as weight in kilograms divided by height in meters squared. General physical and systemic examinations were performed to exclude illness.

Blood pressure was measured by auscultation with a mercury sphygmomanometer and an appropriately sized cuff, in the seated position on the right arm. Measurements were obtained in a quiet room after the procedure had been explained, with efforts to minimize fear, anxiety, talking, laughter, and recent physical activity. Three readings obtained on three separate occasions were averaged. Children whose BP exceeded the 90th percentile were reassessed after four weeks.

### Definitions

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) percentiles were determined according

to the Fourth Report, incorporating age, sex, and height.[2] Hypertension was defined as average SBP and/or DBP at or above the 95th percentile; prehypertension as average SBP or DBP at or above the 90th but below the 95th percentile; and normal BP as values below the 90th percentile. BMI-for-age was classified using the World Health Organization 5-19-year growth reference; > +2 SD denoted obesity.[8] For the reported association analysis, BMI-for-age was grouped as ≤ +2 SD or > +2 SD.

**Statistical Analysis**

Continuous variables are presented as mean ± standard deviation and categorical variables as number (percentage). Independent-samples t tests or Mann-Whitney U tests were used for two-group comparisons as appropriate. Sex-specific Pearson correlation coefficients assessed relations of age, height, and weight with SBP and DBP. Pearson chi-square tests compared BP status by sex. Fisher exact tests compared hypertension prevalence between BMI categories. Binomial 95% confidence intervals (CIs) were calculated by the Wilson method, and prevalence ratios (PRs) with log-based 95% CIs compared BMI categories. Statistical significance was set at two-sided $P < 0.05$. Analyses were performed using SPSS version 18.

**Table 1. Blood pressure status according to sex (N = 1,289)**

| BP | Status | Boys (n = 580), n (%) | Girls (n = 709), n (%) | Total, n (%) | *P* value |
|---|---|---|---|---|---|
| SBP | Normal | 569 (98.1) | 621 (87.6) | 1,190 (92.3) | $1.57 \times 10^{-11}$ |
| | Prehypertension | 4 (0.7) | 33 (4.7) | 37 (2.9) | |
| | Hypertension | 7 (1.2) | 55 (7.8) | 62 (4.8) | |
| | **Total** | **580 (100.0)** | **709 (100.0)** | **1,289 (100.0)** | |
| DBP | Normal | 488 (84.1) | 578 (81.5) | 1,066 (82.7) | 0.000806 |
| | Prehypertension | 51 (8.8) | 41 (5.8) | 92 (7.1) | |
| | Hypertension | 41 (7.1) | 90 (12.7) | 131 (10.2) | |
| | **Total** | **580 (100.0)** | **709 (100.0)** | **1,289 (100.0)** | |

Percentages use sex-specific column denominators. SBP, systolic blood pressure; DBP, diastolic blood pressure. *P* values are from Pearson chi-square tests (2 df).

**Ethics**

Ethics committee approval was obtained before study initiation. Written parental consent and child assent were obtained.

**RESULTS**

The analysis included 1,289 children: 580 boys (45.0%) and 709 girls (55.0%). Mean age was 12.90 ± 2.12 years among boys and 11.78 ± 2.09 years among girls. Obesity was present in 64 children (5.0%): 42 boys (7.2%) and 22 girls (3.1%).

SBP was normal in 1,190 children (92.3%), prehypertensive in 37 (2.9%), and hypertensive in 62 (4.8%; 95% CI, 3.8%-6.1%). DBP was normal in 1,066 (82.7%), prehypertensive in 92 (7.1%), and hypertensive in 131 (10.2%; 95% CI, 8.6%-11.9%). Fifty-five children (4.3%) had both systolic and diastolic hypertension; 138 had either or both, giving an overall hypertension prevalence of 10.7% (95% CI, 9.1%-12.5%).

BP status differed by sex for both components. Systolic hypertension was present in 7 boys (1.2%) and 55 girls (7.8%; $P = 1.57 \times 10^{-11}$); diastolic hypertension was present in 41 boys (7.1%) and 90 girls (12.7%; $P = 0.000806$) (Table 1).

Age-specific mean SBP and DBP generally increased across the studied age range, although the pattern was not uniform in every age-sex group (Figure 1).

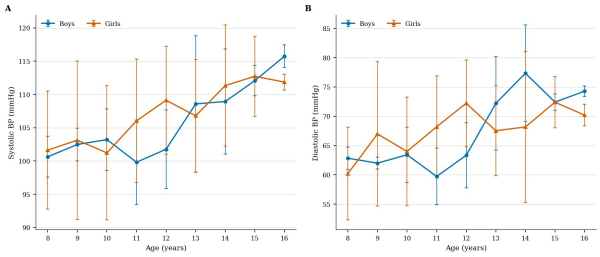



**Figure 1. Age- and sex-specific mean systolic and diastolic blood pressure. Points show means; error bars show standard deviations.**

Hypertension was more frequent among children with BMI-for-age > +2 SD. Systolic hypertension affected 12 of 64 children with obesity (18.8%) and 50 of 1,225 children in the ≤ +2 SD group (4.1%; PR, 4.59; 95% CI, 2.58-8.19; $P = 0.0000245$). Corresponding diastolic hypertension frequencies were 16 of 64 (25.0%) and 115 of 1,225 (9.4%; PR, 2.66; 95% CI, 1.68-4.21; $P = 0.000362$) (Table 2).

**Table 2. Blood pressure status according to BMI-for-age category**

| BP | BMI-for-age category | Normal, n (%) | Prehypertension n (%) | Hypertension, n (%) | Hypertension PR (95% CI) | *P* value |
|---|---|---|---|---|---|---|
| SB | ≤ +2 SD | 1,138 | 37 (3.0) | 50 (4.1) | 1.00 (refere | 0.0000245 |

| BP | BMI-for-age category | Normal, n (%) | Prehypertension n (%) | Hypertension, n (%) | Hypertension PR (95% CI) | *P* value |
|---|---|---|---|---|---|---|
| P | (n = 1,225) | (92.9) | | | nce) | |
| | > +2 SD (n = 64) | 52 (81.3) | 0 (0.0) | 12 (18.8) | 4.59 (2.58-8.19) | |
| DBP | ≤ +2 SD (n = 1,225) | 1,026 (83.8) | 84 (6.9) | 115 (9.4) | 1.00 (reference) | 0.000362 |
| | > +2 SD (n = 64) | 40 (62.5) | 8 (12.5) | 16 (25.0) | 2.66 (1.68-4.21) | |

Percentages use BMI-category row denominators. BMI, body mass index; CI, confidence interval; PR, prevalence ratio; SBP, systolic blood pressure; DBP, diastolic blood pressure; SD, standard deviation. BMI-for-age > +2 SD denotes obesity. PR compares hypertension prevalence with the ≤ +2 SD category. Two-sided *P* values are from Fisher exact tests for hypertension versus no hypertension.

Age-specific hypertension prevalence varied across sex and BP component (Figure 2). Systolic hypertension among boys occurred only at ages 13 and 14 years, whereas the highest age-specific prevalence among girls occurred at age 9 years. Diastolic hypertension peaked at age 14 years among boys and age 9 years among girls.

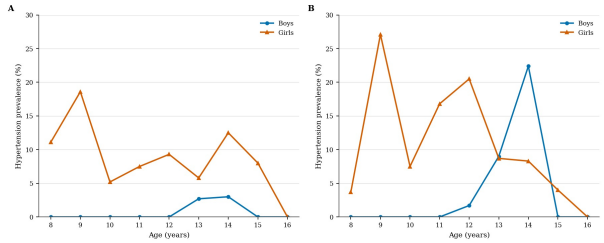



**Figure 2. Age-specific hypertension prevalence by sex: (A) systolic; (B) diastolic. Percentages use the number of boys or girls at each age as denominators.**

Age, height, and weight correlated positively with SBP and DBP in both sexes. Coefficients ranged from 0.18 for height and DBP among girls to 0.59 for weight and DBP among boys (Table 3).

**Table 3. Correlations of age and anthropometric measures with blood pressure**

| Characteristic | Sex | Blood pressure | r | *P* value |
|---|---|---|---|---|
| Age | Boys | SBP | 0.53 | $2.55 \times 10^{-43}$ |
| | Boys | DBP | 0.58 | $1.94 \times 10^{-53}$ |
| | Girls | SBP | 0.34 | $1.21 \times 10^{-20}$ |
| | Girls | DBP | 0.23 | $5.77 \times 10^{-10}$ |
| Height | Boys | SBP | 0.46 | $1.04 \times 10^{-31}$ |
| | Boys | DBP | 0.57 | $2.82 \times 10^{-51}$ |
| | Girls | SBP | 0.37 | $2.01 \times 10^{-24}$ |
| | Girls | DBP | 0.18 | 0.00000141 |
| Weight | Boys | SBP | 0.50 | $5.16 \times 10^{-38}$ |
| | Boys | DBP | 0.59 | $1.11 \times 10^{-55}$ |
| | Girls | SBP | 0.49 | $4.29 \times 10^{-44}$ |
| | Girls | DBP | 0.27 | $2.62 \times 10^{-13}$ |

Correlation coefficients are sex-specific. SBP, systolic blood pressure; DBP, diastolic blood pressure. Two-sided *P* values were calculated from r and the corresponding sex-specific sample size.

## DISCUSSION

This school-based study identified hypertension in 10.7% of participants, with a higher prevalence of diastolic than systolic hypertension. Girls had higher unadjusted systolic and diastolic hypertension prevalence than boys. BP was positively correlated with age, height, and weight, and obesity was associated with substantially higher systolic and diastolic hypertension prevalence. Together, these findings show that BP assessment and anthropometric evaluation identify overlapping groups of schoolchildren who may benefit from follow-up.

Published Indian estimates of pediatric hypertension vary widely. Anand and Tandon reported 0.46%, whereas Chadha and colleagues reported 11.7%.[9,10] Taksande and colleagues found 5.75%, and Narayanappa and colleagues reported 2.0% in rural and 2.9% in urban schoolchildren.[11,12] Component-specific estimates reported by Srinivas and Baradol were lower, while a study from urban Surat reported hypertension in 6.48%.[5,13,14] The present overall estimate lies near the upper end of this range. Differences in age structure, geographic setting, cuff and measurement procedures, number of readings, diastolic Korotkoff phase, and diagnostic reference standards can materially alter prevalence estimates.[11,13,14]

The comparatively high diastolic hypertension prevalence merits careful interpretation. The Fourth Report uses the fifth Korotkoff sound for DBP, whereas some cited Indian school studies used the fourth sound.[2,13,14] Variation in the endpoint used to define DBP can shift percentile classification and complicate direct comparison. Nevertheless, measurements in this study were repeated on separate occasions, elevated

readings were reassessed, and age-, sex-, and height-specific thresholds were applied, reducing misclassification from a single screening reading.

The higher prevalence among girls differed from several Indian reports. Durrani and Waseem found similar overall prevalence in boys and girls, while studies from Kolar and Karnataka reported higher estimates among boys.[13-15] Sex differences in pediatric BP may vary with the age and height composition of the sample, pubertal maturation, and contextual factors. In this study, the distributions of age differed between boys and girls and the comparisons were not adjusted for potential confounders; consequently, the observed sex association should be regarded as descriptive rather than causal.

The positive correlations with age, height, and weight agree with studies by Taksande, Durrani, and Saha and colleagues.[11,15,16] BP rises with growth and body size, which is why pediatric interpretation incorporates age, sex, and height. The coefficients were consistently positive but differed by sex and BP component, emphasizing that a single anthropometric measure does not fully account for BP variation.

Obesity showed the strongest anthropometric association. Children with BMI-for-age > +2 SD had 4.59 times the prevalence of systolic hypertension and 2.66 times the prevalence of diastolic hypertension compared with other children. Similar relationships between excess body mass and elevated BP have been reported in schoolchildren by Sorof and colleagues and in Indian studies.[11,15,17,18] In contrast, the Bogalusa Heart Study found that secular increases in obesity were not accompanied by parallel increases in mean BP, showing that population trends and individual-level associations are not interchangeable.[19] The cross-sectional design here supports association, not a conclusion that obesity caused hypertension.

The large sample, stratified school selection, standardized auscultatory technique, repeated measurements, and use of pediatric percentile criteria are important strengths. Incorporating BP measurement into periodic school health assessments, together with height, weight, and BMI, could improve recognition of children with elevated values. School screening should be linked to clinical assessment and evaluation before treatment decisions are made.

## CONCLUSION

Among children aged 8-16 years attending urban private schools in Bangalore, 10.7% had systolic and/or diastolic hypertension, with diastolic hypertension more frequent than systolic hypertension. Girls had higher unadjusted prevalence than boys, BP correlated positively with age, height, and weight, and obesity was strongly associated with both systolic and diastolic hypertension. Standardized BP and anthropometric assessment within school health services may facilitate early identification and appropriate follow-up.

### Limitations

The cross-sectional design precludes temporal or causal inference. Restriction to urban private schools limits generalizability to public-school, rural, and out-of-school children. Boys and girls differed in age distribution, and multivariable adjustment for age, pubertal stage, socioeconomic characteristics, diet, activity, and school-level clustering was not performed. Ambience, fasting state, and psychological stress could not be fully controlled, and ambulatory monitoring was not used to assess white-coat hypertension. Parental BP was not measured, so family history depended on parental awareness and reporting.

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