



Original Research Article

PREVALENCE OF HYPERTENSION AMONG SCHOOL CHILDREN IN SHIMLA, HIMACHAL PRADESH: A MULTI-CLUSTER SCHOOL SURVEY

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ABSTRACT

Background: Hypertension precursors originate during childhood, yet routine screening remains underutilised. This study aimed to determine the prevalence of prehypertension and hypertension amongst apparently healthy school children in Shimla, Himachal Pradesh, and evaluate their correlation with Body Mass Index (BMI).

Materials and Methods: A prospective cross-sectional study was conducted amongst 300 children aged 6–16 years using multi-stage cluster sampling. Resting blood pressure (BP) was measured via a standardised auscultatory protocol. To eliminate transient elevations and white-coat effects, initially elevated readings required mandatory confirmation during a follow-up visit at least four weeks later. Participants were categorised using age- and gender-specific Indian Academy of Paediatrics growth percentiles.

Results: Following repeat confirmatory evaluations, 87.67% (n = 263) of participants were normotensive. The confirmed prevalence of prehypertension was 10.0% (n = 30), whilst sustained hypertension was 2.33% (n = 7). Categorical associations between BP status and age groups (p = 0.218) or gender (p = 0.559) were not statistically significant. Conversely, a highly significant association was observed between BMI categories and elevated BP (p < 0.001). Although only 5.0% of the cohort was overweight, this subgroup accounted for 57.14% of all sustained hypertensive cases. A positive family history was also significantly associated with elevated BP (p = 0.005).

Conclusions: Sustained hypertension demonstrates a conservative prevalence amongst school children in Shimla, largely protected by a lean baseline population profile. However, increased adiposity remains the primary determinant of elevated blood pressure, emphasising the necessity of targeted school-based screening.

Keywords: Adolescent, Body Mass Index, Hypertension, Paediatrics, Prehypertension, School Health.

INTRODUCTION

Hypertension is a predominant global public health challenge and a primary risk factor for cardiovascular disease and cerebrovascular morbidity. While cardiovascular events typically manifest in later decades, epidemiological evidence demonstrates that the precursors of hypertension originate during childhood and adolescence, making early screening essential.^[1] Furthermore, blood pressure regulation during adolescence is highly dynamic; longitudinal

tracking indicates that approximately 7% of adolescents classified with prehypertension progress to overt hypertension each year.^[2] However, because symptoms are largely non-specific, elevated childhood blood pressure frequently remains undiagnosed, leading to missed opportunities for early lifestyle and preventive interventions.^[2]

In India, cardiovascular diseases contribute to over 28% of total mortality, with hypertension directly attributable to nearly 11% of all deaths and a substantial proportion of strokes and coronary artery

disease.^[3] Despite this recognized burden, routine blood pressure screening among asymptomatic children is infrequently practiced in standard school health or outpatient clinical care. This neglect is particularly concerning given that large population-based evaluations demonstrate a remarkable proportion of asymptomatic youths presenting with prehypertension or elevated blood pressure readings in real-world settings.^[4] Consequently, pediatric hypertension represents an important, yet under-confirmed, population burden in developing nations like India.^[1]

The transition toward sedentary lifestyles, increased screen time, and altered dietary patterns has led to a rising prevalence of prehypertension and hypertension among Indian school-going children. While several studies have documented this trend across urban and rural corridors in India, standardized data remain significantly limited for high-altitude, hilly regions such as Himachal Pradesh.

Furthermore, obesity has emerged as a consistent determinant of pediatric hypertension. Emerging evidence suggests that South Asian children may develop elevated blood pressure at lower Body Mass Index (BMI) thresholds compared to Western populations due to higher body fat percentages and altered metabolic profiles. This vulnerability necessitates robust, region-specific evidence to inform local preventive strategies. The present study was designed to address this critical gap by assessing blood pressure levels among apparently healthy school-going children aged 6–16 years in Shimla, Himachal Pradesh. By determining the prevalence of prehypertension and sustained hypertension and evaluating their direct correlation with BMI, this research aims to provide a reliable diagnostic foundation for targeted, school-based screening initiatives in the region.

MATERIALS AND METHODS

Study Design and Setting A prospective, school-based cross-sectional study was conducted in Shimla, Himachal Pradesh, India, over a study period of one year. The study protocol was reviewed and approved by the Institutional Ethics Committee of institute. Written informed consent was obtained from the parents or legal guardians of all participants, alongside age-appropriate verbal assent from the children prior to enrolment.

The study population comprised apparently healthy school children aged 6 to 16 years. A multi-stage cluster sampling technique was employed to select representative schools within the Shimla district, ensuring a balanced representation of diverse socio-economic backgrounds. Children with known secondary causes of hypertension, pre-existing renal or cardiovascular diseases, or those currently taking medications known to affect blood pressure (BP) were excluded from the study.

An initial unadjusted sample size of 139 participants was calculated assuming an estimated hypertension prevalence of 10%, an absolute error of 5%, and a standard 95% confidence level. To account for the intracluster correlation inherent in school-based cluster sampling, a design effect of 1.98 was applied. This design effect was derived using an anticipated average cluster size of 50 students per school and an intraclass correlation coefficient of 0.02. Consequently, the adjusted sample size requirement increased to 276 students, necessitating the selection of six distinct school clusters. The final recruited sample size was rounded up to 300 students (154 boys and 146 girls), comprising exactly six clusters of 50 students each.

Data Collection and Anthropometric Measurements

Demographic data, including age, gender, and a detailed family history of hypertension, was recorded using a pre-tested, structured proforma. Anthropometric measurements were obtained using standardised protocols:

- **Height:** Measured to the nearest 0.1 cm using a portable stadiometer with the child standing barefoot in the standard anatomical position.
- **Weight:** Recorded to the nearest 0.1 kg using a calibrated digital scale.
- **Body Mass Index (BMI):** Calculated as weight in kilograms divided by the square of height in metres (kg/m^2). Participants were categorised into normal weight, overweight, or obese based on age- and gender-specific Indian Academy of Paediatrics (IAP) growth charts.^[5]

Blood Pressure Measurement Protocol

Blood pressure was measured using a validated aneroid sphygmomanometer with an appropriate cuff size (bladder width covering at least 40% of the arm circumference at the point midway between the olecranon and the acromion, and bladder length covering 80–100% of the circumference). Measurements were taken in a quiet room after the child had rested seated for at least five minutes with the right arm supported at heart level. Three separate readings were obtained at intervals of three minutes, and the mean value was recorded. To eliminate the "white-coat effect" and avoid misclassifying transient elevations, any participant exhibiting prehypertension or hypertension during the initial screening underwent a mandatory follow-up evaluation at least four weeks later. Sustained hypertension was defined strictly as elevated BP confirmed across these repeated visits, classified according to standard paediatric normative percentiles adjusted for age, gender, and height.

Statistical Analysis: Data was entered into MS excel and analysed using Epi info statistical software. Categorical variables were expressed as frequencies and percentages, whilst continuous variables were presented as means alongside standard deviations. The prevalence of prehypertension and sustained hypertension was calculated with 95% confidence

intervals. Associations between BP categories and independent variables (such as BMI categories, age groups, and family history) were evaluated using the Chi-square test. A two-tailed p-value <0.05 was considered statistically significant.

RESULTS

Baseline Characteristics of the Study Population

A total of 300 apparently healthy school children were enrolled and completed the evaluation. The mean age of the study participants was 12.65 ±2.55 years (range: 6 to 16 years), with a median age of 13 years. Stratification by age groups revealed that 42 participants (14.0%) were aged 6–9 years, 78 (26.0%) were aged 10–12 years, and 180 (60.0%) were aged 13–16 years. The cohort demonstrated a nearly equal gender distribution, comprising 154 boys (51.33%) and 146 girls (48.67%).

Hemodynamically, the mean systolic blood pressure (SBP) across the entire cohort was 112.48 ± 10.3 mm Hg (range: 89–143 mm Hg), whilst the mean resting diastolic blood pressure (DBP) was 72.4 ± 6.83 mm

Hg (range: 60–93 mm Hg). Both systolic and diastolic pressures demonstrated a highly significant, positive linear correlation with advancing age ($r = 0.6$, $p < 0.001$, 95% CI [0.5, 0.7]).

Prevalence of Prehypertension and Sustained Hypertension

The vast majority of participants ($n = 263$; 87.67%) were confirmed to be normotensive. The overall prevalence of elevated blood pressure categories was 12.33%, consisting of 30 prehypertensive children (10.0%) and 7 children with confirmed sustained hypertension (2.33%). [Table 1]

Although the proportion of prehypertension and hypertension increased progressively across the advancing age strata, with no hypertensive cases observed in the 6–9 years category, 3 cases (3.85%) in the 10–12 years category, and 4 cases (2.22%) in the 13–16 years category, this overarching association between age group and clinical blood pressure status did not reach statistical significance ($p = 0.218$). Similarly, the distribution of sustained hypertension and prehypertension showed no statistically significant difference between boys and girls ($p = 0.559$).

Table 1: Distribution of confirmed blood pressure status among the study participants

Blood Pressure Status	Frequency (n)	Percentage (%)	95% Confidence Interval
Normotensive	263	87.67%	83.5% – 91.0%
Pre-hypertensive	30	10.00%	7.0% – 13.9%
Hypertensive (Sustained)	7	2.33%	1.0% – 4.7%
Total	300	100.00%	—

Association between Body Mass Index (BMI) and Blood Pressure

Anthropometric evaluations revealed a mean BMI of 17.07 ±2.62 kg/m² (range: 11.89 to 30.86 kg/m²). According to standard age- and gender-specific IAP percentiles, 284 participants (94.67%) were categorised as having a normal BMI, 15 (5.00%) were overweight, and 1 (0.33%) was classified as obese (Table 2).

A highly significant statistical association was observed between BMI categories and confirmed blood pressure status ($p < 0.001$). The data demonstrated a pronounced risk concentration effect

among participants with increased adiposity. Amongst children with a normal BMI, only 1.06% ($n = 3$) exhibited sustained hypertension, and 9.15% ($n = 26$) were prehypertensive. Conversely, amongst overweight children, the prevalence of confirmed hypertension rose sharply to 26.67% ($n = 4$), with an additional 26.67% ($n = 4$) manifesting prehypertension. Consequently, whilst overweight children constituted merely 5.0% of the total sample, they accounted for over half (57.14%) of the entire burden of confirmed hypertension in this population. The single participant classified as obese was found to be normotensive.

Table 2: Association between Body Mass Index (BMI) categories and blood pressure status

BMI Category	Normotensive (n, %)	Prehypertensive (n, %)	Hypertensive (n, %)	Total (n)	p-value
Normal	255 (89.79%)	26 (9.15%)	3 (1.06%)	284	< 0.001*
Overweight	7 (46.67%)	4 (26.67%)	4 (26.67%)	15	
Obese	1 (100.00%)	0 (0.00%)	0 (0.00%)	1	
Total	263 (87.67%)	30 (10.00%)	7 (2.33%)	300	

*Chi-square test

A continuous variable further confirmed a highly significant, positive linear correlation between increasing BMI values and high blood pressure ($r = 0.4$, $p < 0.001$, 95% CI [0.3, 0.5]) and increasing age

($r = 0.6$, $p < 0.001$, 95% CI [0.4, 0.5]), solidifying elevated adiposity as the primary determinant of elevated blood pressure in this cohort. [Table 3]

Table 3: Correlation and Association of Clinical Variables with Blood Pressure Status

Variable	Statistical Test	Value (r / χ^2)	Significance (p)
Age	Pearson's Correlation (r)	0.6	< 0.001
Age Group	Chi-Square (χ^2)	—	0.218

Body Mass Index	Pearson's Correlation (r)	0.4	< 0.001
BMI Category	Chi-Square (χ^2)	—	< 0.001
Family History	Chi-Square (χ^2)	—	0.005
Gender	Chi-Square (χ^2)	—	0.559

While overweight children represented only 5% of the total sample, they accounted for 57.14% of the confirmed hypertensive cases. A positive family history of hypertension was reported by 20.67% of the participants and was significantly associated with elevated blood pressure categories ($p = 0.005$). No significant difference in the prevalence of prehypertension or hypertension was found between boys and girls ($p = 0.559$).

DISCUSSION

The present study establishes the prevalence of prehypertension and sustained hypertension amongst apparently healthy school children aged 6–16 years in the high-altitude urban setting of Shimla, whilst evaluating the critical clinical determinants driving early vascular risk.

Following rigorous, repeated confirmatory evaluations to eliminate the "white-coat effect" and transient autonomic elevations, the prevalence of sustained hypertension was confirmed at 2.33%, alongside a prehypertension burden of 10.0%. This conservative burden aligns closely with other Indian epidemiological evaluations that employ strict repeat-visit protocols. For instance, Sayeemuddin et al. in a large cohort of school children aged 6–16 years in Southern India, documented an overall hypertension prevalence of 2.42%.^[6] Similarly, Saleem et al. reported a confirmed hypertension rate of 2.84% amongst urban school children in Kerala.^[7] Conversely, our findings stand in contrast to studies reporting substantially higher prevalence figures, such as Borah et al. in North-East India,^[8] (7.6%) and Sundar et al.,^[9] in Chennai (21.5%). Much of this inter-study heterogeneity can be attributed to methodological variance, specifically the reliance on single-visit screenings versus mandatory follow-up confirmation. As demonstrated in recent longitudinal tracking by Gouroumourty et al. in Central India, elevated blood pressure readings decline progressively across repeated visits due to anxiety attenuation and regression to the mean, yielding a true sustained prevalence of 1.4%.^[10] Our findings underscore the necessity of standardised, multi-visit protocols to prevent the over-diagnosis of paediatric hypertension.

The most striking finding of the present investigation is the robust, highly significant association between BMI and confirmed high blood pressure ($p < 0.001$), supported by a significant linear correlation ($r = 0.4$, $p < 0.001$). Although the overall burden of overweight and obesity in this high-altitude cohort is low, with 94.67% manifesting a normal BMI and only 5.0% classified as overweight, the data revealed a profound risk concentration effect. Overweight

children contributed to 57.14% of the entire confirmed hypertensive burden.

The disproportionate clustering of elevated BP within higher BMI tiers is strongly concordant with published literature. Mohan et al. evaluating urban and rural adolescents in North India, demonstrated a distinct graded association where the relative risk of sustained hypertension increased multi-fold amongst overweight (RRR 2.56) and obese (RRR 7.21) youths.^[11] Similarly, the comprehensive meta-analysis by Daniel et al. which pooled data from 27,682 Indian adolescents, identified increased adiposity as the most consistent modifiable driver of elevated blood pressure.^[12]

Pathophysiologically, excess adiposity triggers sympathetic overactivity, insulin resistance, and structural vascular remodelling. Importantly, our data indicate that population-level blood pressure metrics are intricately tied to local anthropometric profiles; the low overall prevalence of hypertension (2.33%) in Shimla is largely protective, driven by the low baseline prevalence of childhood obesity in the region compared to metropolitan corridors. Resting systolic and diastolic blood pressures demonstrated a highly significant, positive correlation with advancing age ($r = 0.6$, $p < 0.001$). This physiological upward shift reflects normal somatic growth, escalating cardiac output, and neurohormonal changes associated with pubertal maturation.

Categorically, the proportion of prehypertension and sustained hypertension increased progressively from early childhood (6–9 years) into mid-to-late adolescence (13–16 years). Although this categorical distribution did not achieve statistical significance ($p = 0.218$) due to less absolute number of confirmed hypertensive cases ($n = 7$). Patel et al. studying schoolchildren in Central India, confirmed age and height as the primary physiological determinants of resting blood pressure, noting a sharp uptick in clinical prehypertension during the adolescent transition.^[13]

A positive family history of hypertension was reported by 20.67% of the participants and demonstrated a statistically significant association with elevated blood pressure categories ($p = 0.005$). Prehypertension was nearly twice as common amongst children with a positive parental history (16.13%) compared to those without (8.40%). This familial clustering aligns with findings from Saleem et al.,^[7] and Sundar et al.,^[9] reinforcing that inherited genetic susceptibilities (such as altered renal sodium handling or vascular tone) interact synergistically with shared household environments, including dietary salt patterns and lifestyle habits.

No statistically significant association was observed between gender and blood pressure status ($p = 0.559$), indicating an equal vulnerability amongst boys and

girls. This gender neutrality mirrors the findings of Borah et al.^[8] and Patel et al.^[13] While some adolescent-heavy cohorts report a male predominance due to higher screen time or central adiposity, the balanced gender distribution and uniformly lean BMI profile of the Shimla cohort likely prevented any gender-based divergence in vascular resistance.

The present study strengths include the strictly standardised blood pressure measurement protocol and the mandatory confirmation of elevated readings across repeated follow-up visits spaced at least four weeks apart, along with the implementation of a multi-stage cluster sampling technique within schools. However, certain limitations must be acknowledged, primarily the cross-sectional design, which precludes causal inferences regarding the onset of hypertension or its longitudinal tracking into adulthood. Also 24-hour ambulatory blood pressure monitoring was not utilised, along with behavioural variables such as exact daily dietary salt intake, physical activity durations, and screen time were not quantitatively assessed. Finally, the relatively lean anthropometric profile of the participants, though accurately reflecting the Shimla school kids may limit the direct generalisability of these findings to metropolitan regions with substantially higher burdens of childhood adiposity.

CONCLUSION

In conclusion, this study demonstrates that asymptomatic prehypertension and sustained clinical hypertension are actively present amongst apparently healthy school children in Shimla. Increased adiposity serves as a primary, critical determinant driving elevated blood pressure even during childhood, acting synergistically with hereditary factors as evidenced by the significant association with a positive family history. Ultimately, these results underscore the critical public health necessity of integrating routine blood pressure screenings into standard school health programmes. Early identification of elevated blood pressure, coupled with targeted primary interventions directed against childhood overweight and obesity, remains paramount in preventing the future adult burden of cardiovascular disease.

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