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PREVALENCE AND LIFESTYLE CORRELATES OF ASYMPTOMATIC ELEVATED BLOOD PRESSURE AND HYPERTENSION AMONG SCHOOL-GOING ADOLESCENTS AGED 10-17 YEARS IN CENTRAL INDIA: A CROSS-SECTIONAL STUDY

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ABSTRACT **Background:** Elevated blood pressure during adolescence is commonly asymptomatic and may be missed unless blood pressure is measured systematically. **Objective:** To estimate the prevalence of asymptomatic elevated blood pressure and hypertension and to assess associated lifestyle and anthropometric correlates among school-going adolescents aged 10-17 years in Central India. **Methods:** This school-based cross-sectional study included 300 students from grades VI-XII in two schools of Indore, Madhya Pradesh, between April 2024 and September 2025. A pre-tested questionnaire based on Global School-based Student Health Survey domains recorded dietary and lifestyle exposures. Height, weight, and blood pressure were measured; three blood pressure readings were taken at three-minute intervals, and the average of the last two readings was classified using AAP 2017 and IAP 2022 criteria. Associations with raised blood pressure were assessed using appropriate statistical tests. **Results:** The mean age was 13.33 ± 2.34 years; 151 (50.3%) participants were male. Raised blood pressure was present in 49 (16.3%) adolescents, including elevated blood pressure in 26 (8.7%) and stage 1 hypertension in 23 (7.7%). Raised blood pressure was more frequent in late adolescence than early adolescence (24.5% vs 9.3%, p<0.001). It was strongly associated with BMI category, high salt intake, fast-food consumption, lower physical activity, higher screen time (all p<0.001), and inadequate sleep (p=0.047), but not with sex (p=0.376), family history (p=0.215), fruit and vegetable intake (p=0.187), or caffeine intake (p=1.000). **Conclusion:** Nearly one in six school-going adolescents had asymptomatic raised blood pressure. The clustering with modifiable exposures supports routine school-based blood pressure screening and focused counselling on weight, salt and fast-food intake, physical activity, screen time, and sleep.

KEYWORDS : adolescent hypertension; elevated blood pressure; school health; obesity; lifestyle risk factors

INTRODUCTION

Pediatric hypertension is now recognised as an early marker of cardiovascular risk rather than a problem confined to adulthood. A recent global systematic review estimated sustained hypertension in 3.89% of children and adolescents and occasional hypertension in 11.85%, with substantially higher risk among those with overweight or obesity [1]. Standardised classification has therefore become important; the 2017 American Academy of Pediatrics (AAP) guideline replaced prehypertension with elevated blood pressure and simplified thresholds for adolescents [2]. The Indian Academy of Pediatrics (IAP) standard treatment guidance follows a similar practical approach for pediatric practice [3].

The clinical relevance of early blood pressure elevation lies in its persistence and biological effect. Childhood and adolescent blood pressure tracks into adulthood and is associated with later cardiovascular outcomes [4]. Pediatric ambulatory hypertension has also been linked with target-organ damage, including adverse vascular and cardiac profiles [5]. Because most adolescents with raised blood pressure do not have symptoms, detection depends on routine measurement rather than clinical complaints.

Indian data show that high blood pressure in adolescents is not uncommon. Analysis of the Comprehensive National Nutrition Survey found high blood pressure associated with overweight, obesity, and other cardiometabolic risk factors [6]. At the same time, estimates vary widely because measurement technique, number of readings, age distribution, and definitions differ across studies. Schools provide a practical setting for screening and for assessment of diet, physical activity, screen exposure, sleep, and related behaviours using structured health-survey domains [7]. This study was conducted to estimate the prevalence of asymptomatic elevated blood pressure and hypertension among school-going adolescents aged 10-17 years and to examine associated modifiable risk factors.

MATERIALS AND METHODS

This observational, school-based, cross-sectional, questionnaire-based study was conducted in Indore, Madhya Pradesh, at Rukhma Devi Public School and Shri Barfani Convent School from April 2024 to September 2025. The study population comprised healthy male and female adolescents aged 10-17 years studying in grades VI-XII. Adolescents with cardiac disease, renal disease, chronic illness, psychiatric illness, anxiety disorder, or use of drugs known to influence blood pressure were excluded. Participation was voluntary and consent was obtained before enrolment.

Information on sociodemographic profile, family history, diet, salt intake, fast-food intake, fruit and vegetable intake, caffeine intake, physical activity, screen time, sleep duration, and substance use was collected using a pre-tested proforma based on WHO Global School-based Student Health Survey domains [7]. Height was measured in centimetres and weight in kilograms; BMI was calculated and categorized using Asian-Indian cut-offs recorded for the study. Blood pressure was measured with a digital sphygmomanometer using age-appropriate cuffs on the right arm. Three readings were taken at three-minute intervals, and the average of the last two readings was used for analysis.

Blood pressure was classified according to AAP 2017 and IAP 2022 criteria [2,3]. For analysis, raised blood pressure included both elevated blood pressure and stage 1 hypertension. Data were entered in Microsoft Excel and analysed using SPSS version 20.0. Categorical variables are presented as frequency and percentage; continuous variables as mean ± SD. Associations were assessed using chi-square or Fisher exact test for categorical variables and t-test or ANOVA for continuous variables as applicable. A two-sided p value <0.05 was considered statistically significant. Institutional Ethics Committee approval was obtained.

RESULTS

A total of 300 adolescents were included. The mean age was 13.33 ± 2.34 years; 161 (53.7%) were aged 10-13 years and 139 (46.3%) were aged 14-17 years. The sex distribution was nearly equal, with 151 (50.3%) males and 149 (49.7%) females. High and higher secondary students formed 161 (53.7%) of the sample. The mean BMI was 21.14 ± 2.52 kg/m²; 37 (12.3%) were underweight, 211 (70.3%) normal weight, 24 (8.0%) overweight, and 28 (9.3%) obese. High salt intake was reported by 107 (35.7%), fast-food intake on at least three days per week by 75 (25.0%), screen time above two hours per day by 123 (41.0%), and sleep below eight hours by 118 (39.3%) (Table 1).

Table 1. Baseline and behavioral profile of study participants (N=300)

Characteristic	Category	n (%)
Age group (years)	10-13	161 (53.7)
	14-17	139 (46.3)
Sex	Male	151 (50.3)
	Female	149 (49.7)
School grade	Middle school, Class VI-VIII	139 (46.3)
	High and higher secondary, Class IX-XII	161 (53.7)
BMI category	Underweight	37 (12.3)
	Normal weight	211 (70.3)
	Overweight	24 (8.0)
	Obese	28 (9.3)
Family history of hypertension	Yes	52 (17.3)
	No	248 (82.7)
Daily salt intake	Normal	193 (64.3)
	High	107 (35.7)
Fast-food consumption per week	0 days	72 (24.0)
	1-2 days	153 (51.0)
	3-4 days	49 (16.3)
	>=5 days	26 (8.7)
Fruit/vegetable intake	Adequate	249 (83.0)
	Inadequate	51 (17.0)
Caffeine intake	Yes	216 (72.0)
	No	84 (28.0)
Physical activity per week	0 days	31 (10.3)
	1-2 days	40 (13.3)
	3-4 days	151 (50.3)
	>=5 days	78 (26.0)
Daily screen time	Under 1 hour	54 (18.0)
	1-2 hours	123 (41.0)
	3-4 hours	72 (24.0)
	5-6 hours	27 (9.0)
	Over 6 hours	24 (8.0)
Sleep duration	Adequate, 8-10 hours	182 (60.7)
	Inadequate, under 8 hours	118 (39.3)
Substance use in past 30 days	Yes	17 (5.7)
	No	283 (94.3)

Data are presented as number (percentage).

Normal blood pressure was recorded in 251 (83.7%) participants. Raised blood pressure was present in 49 (16.3%), comprising elevated blood pressure in 26 (8.7%) and stage 1 hypertension in 23 (7.7%) (Figure 1). Mean systolic and diastolic blood pressure were higher in males than females (114.52 ± 7.23 vs 112.31 ± 6.45 mmHg, p=0.012; 73.18 ± 5.84 vs 71.22 ± 5.12 mmHg, p=0.015). Late adolescents had higher mean systolic and diastolic blood pressure than early adolescents (115.82 ± 7.54 vs 110.45 ± 6.18 mmHg; 74.21 ± 5.43 vs 70.85 ± 4.92 mmHg; both p<0.001).

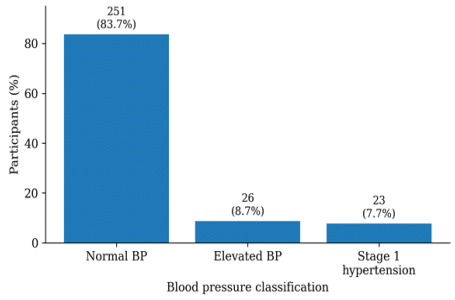

Figure 1. Distribution of participants according to blood pressure classification.

Raised blood pressure was significantly more frequent in late adolescence than early adolescence (24.5% vs 9.3%, p<0.001). It did not differ significantly by sex (male 18.5%, female 14.1%; p=0.376). BMI category showed the strongest association: raised blood pressure was present in 2.7% of underweight, 2.8% of normal-weight, 79.2% of overweight, and 82.1% of obese adolescents (p<0.001) (Figure 2). High salt intake (28.0% vs 9.8%, p<0.001), increasing fast-food intake, lower physical activity, higher screen time (all p<0.001), and inadequate sleep (22.0% vs 12.6%, p=0.047) were significantly associated with raised blood pressure. Family history, fruit and vegetable intake, and caffeine intake were not statistically significant (Table 2).

Table 2. Association of participant characteristics and lifestyle factors with blood pressure status

Variable	Category	Normal BP n (%)	Raised BP n (%)	Total n	p value
Age group (years)	10-13	146 (90.7)	15 (9.3)	161	<0.001
	14-17	105 (75.5)	34 (24.5)	139	
Sex	Male	123 (81.5)	28 (18.5)	151	0.376
	Female	128 (85.9)	21 (14.1)	149	
BMI category	Underweight	36 (97.3)	1 (2.7)	37	<0.001
	Normal weight	205 (97.2)	6 (2.8)	211	
	Overweight	5 (20.8)	19 (79.2)	24	
	Obese	5 (17.9)	23 (82.1)	28	
Family history of hypertension	Yes	40 (76.9)	12 (23.1)	52	0.215
	No	211 (85.1)	37 (14.9)	248	
Daily salt intake	Normal	174 (90.2)	19 (9.8)	193	<0.001
	High	77 (72.0)	30 (28.0)	107	
Fast-food consumption per week	0 days	71 (98.6)	1 (1.4)	72	<0.001
	1-2 days	151 (98.7)	2 (1.3)	153	
	3-4 days	25 (51.0)	24 (49.0)	49	
	>=5 days	4 (15.4)	22 (84.6)	26	
Fruit/vegetable intake	Adequate	212 (85.1)	37 (14.9)	249	0.187
	Inadequate	39 (76.5)	12 (23.5)	51	
Caffeine intake	No	70 (83.3)	14 (16.7)	84	1.000
	Yes	181 (83.8)	35 (16.2)	216	
Physical activity per week	0 days	6 (19.4)	25 (80.6)	31	<0.001
	1-2 days	21 (52.5)	19 (47.5)	40	
	3-4 days	148 (98.0)	3 (2.0)	151	
	>=5 days	76 (97.4)	2 (2.6)	78	
Daily screen time	Under 1 hour	53 (98.1)	1 (1.9)	54	<0.001
	1-2 hours	119 (96.7)	4 (3.3)	123	
	3-4 hours	59 (81.9)	13 (18.1)	72	
	5-6 hours	10 (37.0)	17 (63.0)	27	
	Over 6 hours	10 (41.7)	14 (58.3)	24	
Sleep duration	Adequate, 8-10 hours	159 (87.4)	23 (12.6)	182	0.047
	Inadequate, under 8 hours	92 (78.0)	26 (22.0)	118	

Percentages are row percentages. Raised BP includes elevated blood pressure and stage 1 hypertension. p values are reported to three decimal places.

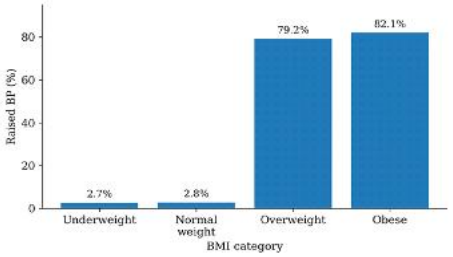

Figure 2. Proportion of raised blood pressure according to BMI category.

DISCUSSION

This school-based study found asymptomatic raised blood pressure in 16.3% of adolescents, with 8.7% having elevated blood pressure and 7.7% having stage 1 hypertension. The finding represents a meaningful screening burden: these students were apparently healthy, and elevated readings would probably have remained unnoticed without systematic measurement. The estimate is higher than the pooled prevalence of adolescent hypertension reported in an Indian systematic review [8], but the present outcome combined elevated blood pressure and stage 1 hypertension and was based on a single school-session assessment.

Indian school and community studies have reported variable estimates. Daniel et al. found a high prevalence of hypertension in rural Haryana when AAP 2017 criteria were applied [9], whereas Mohan et al. reported lower sustained hypertension rates after repeat measurements in North Indian adolescents [10]. Banerjee et al. also reported hypertension among school-going adolescents in Nagpur and identified lifestyle and anthropometric determinants [11]. The wide range across studies is expected because single-visit screening tends to detect more raised readings than repeated or ambulatory confirmation.
The clearest association in this study was with BMI. More than three-fourths of overweight and obese adolescents had raised blood pressure, compared with less than 3% of normal-weight adolescents. This steep gradient is biologically plausible because excess adiposity is linked with sympathetic activation, insulin resistance, vascular dysfunction, and altered renal sodium handling. It also explains why age and sex differences in mean blood pressure may not translate into independent categorical differences once weight and lifestyle exposures cluster in the same adolescents.

Dietary and behavioural patterns showed a consistent direction. High salt intake and frequent fast-food consumption were strongly associated with raised blood pressure, aligning with evidence that sodium intake is positively related to pediatric blood pressure [12]. Lower physical activity was associated with a sharp rise in raised blood pressure, while intervention evidence supports physical activity as a practical means of reducing blood pressure in children and adolescents [13]. Higher screen time and shorter sleep were also significant; these findings are compatible with recent evidence linking prolonged screen exposure and insufficient weekday sleep with hypertension risk in adolescents [14,15]. The absence of significant associations with family history, fruit and vegetable intake, and caffeine intake may reflect limited power, self-reporting, or mediation through BMI and sedentary behaviour.

The findings support a simple school-health message: blood pressure measurement should be paired with counselling on body weight, salt and fast-food intake, physical activity, screen exposure, and sleep hygiene. A single school visit should not be used to label a child permanently as hypertensive, but it can identify adolescents who need repeat measurement, clinical review, and early lifestyle guidance.

LIMITATIONS

The cross-sectional design cannot establish causality. The study was limited to two schools in one city, so generalisability may be restricted. Dietary intake, activity, screen time, sleep, caffeine intake, and substance use were self-reported and may be affected by recall or social desirability bias. Blood pressure was measured during one school session; therefore, sustained hypertension could not be confirmed by repeat visits or ambulatory monitoring.

CONCLUSION

Asymptomatic raised blood pressure was present in nearly one in six school-going adolescents aged 10-17 years. Raised blood pressure clustered with late adolescence, excess BMI, high salt and fast-food intake, low physical activity, higher screen time, and inadequate sleep. School-based blood pressure screening, followed by repeat confirmation and focused lifestyle counselling, offers a feasible strategy for early cardiovascular risk reduction in adolescents.

DECLARATIONS

Ethical approval: Institutional Ethics Committee approval was obtained before initiation of the study.

Conflict of interest: Nil.
Source of funding: Nil.

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