European Journal of Preventive Cardiology

ESC European Society of Cardiology

Full research paper

European Journal of Preventive Cardiology
0(00) 1–10

DOI: 10.1177/2047487318790056
journals.sagepub.com/home/ejpc
SAGE

Prevalence and determinants of hypertension in apparently healthy schoolchildren in India: A multi-center study

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Abstract

Background: Hypertension in children is often under recognized, especially in developing countries. Data from rural areas of developing countries is particularly lacking.

Objectives: To study prevalence of hypertension and its determinants in apparently health school children from predominantly rural populations of India.

Methods: Apparently healthy schoolchildren ($n = 14{,}957$) aged 5–15 years (mean (standard deviation) age 10.8 (2.8) years; 55.5% boys) at four predominantly rural sites in separate states of India were studied. Systolic and diastolic blood pressures were recorded by trained staff in addition to age, gender, height, weight, type of school and season. Waist circumference was also recorded in 12,068 children. Geographic location and type of school (government, government-aided or private) were used to determine socio-economic status.

Results: Systolic and/or diastolic hypertension was present in 3443 (23%) children. Systolic hypertension was present in 13.6%, diastolic hypertension in 15.3% and both in 5.9%. Isolated systolic hypertension was present in 7.7% while isolated diastolic hypertension was present in 9.4%.

On univariate analysis, age, gender, geographical location, socio-economic status, season and anthropometric parameters (z-scores of height, weight and waist circumference, waist/height ratio and body mass index) were all significantly related to risk of hypertension ($p < 0.0001$ for each). Similar association was observed with weight group (normal, overweight and obese). Multiple regression analysis showed lower age, female gender, richer socio-economic status, certain geographical locations, higher weight and larger waist circumference to be independently associated with a greater risk of hypertension.

Conclusion: There is a high prevalence of hypertension in apparently healthy schoolchildren even in predominantly rural areas of India. Screening and management programs targeted to high risk groups identified may prove cost-effective.

Keywords

Hypertension, children, blood pressure, epidemiology

Received 25 May 2018; accepted 2 July 2018

Introduction

There is increasing interest in blood pressure (BP) and hypertension (HT) in children.[1–3] HT in children has been shown to be associated with HT in adulthood and with cardiovascular risk in later life.[4–8] The adverse effects are shown to increase in the presence of obesity,

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of which the world is currently witnessing an epidemic.[9] The recording of BP has also become easier with widespread availability of reliable oscillometric (digital) BP recording instruments. These can be used by paramedical and even lay people, including parents, to record BP at home or at school.

There is also increasing interest in regional variation in BP and in the prevalence of HT since reports from different parts of world have shown wide variations.[10–13] The pattern may be different in developing countries since obesity is less of a problem there as compared to the Western world. Moreover, children from rural areas are less well studied than their urban counterparts. It will also be important to determine the prevalence of HT in undernourished (rather than overnourished obese) children. We report here the prevalence and factors determining HT in schoolchildren in four predominantly rural areas located in different parts of India.

Methods

This cross-sectional epidemiological study was conducted in primary and secondary schools in four states in India (Haryana, Goa, Gujarat and Manipur) as part of a rheumatic heart disease screening program. Details of the method of the study are already published.[14] Informed consent for the project was gained from each school principal as well as the parents. The study was approved by institutional ethics committees at all sites. Children with known major hepatic, renal, cardiac, or respiratory diseases were excluded. For the current analysis, apparently healthy schoolchildren with completed age of 5–15 years were included ($n = 14957$). The children were screened by clinical examination and echocardiography and those found to have significant heart disease were excluded.

During the survey, trained paramedical staff documented demographic and anthropometric data, including height, weight, and waist circumference. Waist circumference was recorded in 12,068 of the total of 14,957 children (it was not recorded at one site). Children sat and rested for five minutes before measurement of BP. BP was measured in a sitting position by trained medical attendants. It was measured using oscillometric instrument in Haryana (Omron HEM 7080) and Gujarat, anaeroid instrument in Manipur and mercury sphygmomanometer (Diamond(R)) at Goa. The digital and aneroid instruments were calibrated against a mercury sphygmomanometer. Children with a high BP reading underwent a repeat BP measurement by research physicians after an interval of about five minutes and the second reading was taken as the final one. All children with BP values which were normal for their age did not have a repeat BP check. Two cuff sizes were used in this study according to the size of the child. No child was excluded based on BP reading.

Socioeconomic status (SES; "richer," "poorer," or "mixed") was assigned to each school depending on type of school and development of the area where the school was located. This SES was applied to all participating children from that school. The season when BP was measured was taken to be 'summer' for April–September months and 'winter' for other months. HT was defined as given by the established Fourth report using BP according to age and gender tables but with 50th centile for height taken for all children.[7,12,15] We have earlier reported simplified percentile tables and charts derived from the BP measurements of 7761 children from one of these sites (Haryana).[11]

Statistical analysis

Data is presented as mean (standard deviation (SD)) unless specified otherwise. Ninety-five percent confidence intervals were calculated whenever appropriate. The z-scores were used for anthropometric parameters (height, weight, and waist circumference) as standardized values (using age, gender, and site).

For univariate analysis, the Student's t-test was used for comparison of continuous variables and the Chi-square test was used to compare categorical variables between hypertensive and non- hypertensive children. Multiple logistic regression analysis was performed to identify independent predictors of HT. For this purpose, weight, height were divided by 10 to obtain the odds ratio for every 10-unit change rather than one-unit change. Similarly, waist circumference was divided by five for multiple regression. Children were divided into weight categories of normal, overweight, and obese. Overweight was defined as weight in the 85th–95th percentile, while obesity was defined as weight greater than the 95th percentile for age and gender of the child. Graphs of prevalence of HT versus continuous variables like age were plotted using the LOESS curve fitting (local polynomial regression) technique. The shaded areas indicate 95% confidence intervals unless stated otherwise. Values of $p < 0.05$ were considered to be statistically significant. All statistical analyses were done using R version 3.3.3.

Results

Table 1 shows age and gender distribution of children included in the study. Mean (SD) age was 10.8 (2.8) years and 55.5% were males. The mean (SD) height was 136.7 (16.6) cm, weight was 31.5 (11.8) kg, waist circumference was 55.0 (9.8) cm, and body mass index (BMI) was 16.3 (3.1) kg/m^2.

Table 1. Age and gender distribution of children participating in the study.

Age (Completed years)	Girls *n*	Girls % Of whole group	Boys *n*	Boys % Of whole group	Total *n*	Total % Of whole group
5	133	0.9%	188	1.3%	321	2.1%
6	442	3.0%	526	3.5%	968	6.5%
7	539	3.6%	628	4.2%	1167	7.8%
8	611	4.1%	690	4.6%	1301	8.7%
9	653	4.4%	675	4.5%	1328	8.9%
10	740	4.9%	930	6.2%	1670	11.2%
11	629	4.2%	817	5.5%	1446	9.7%
12	788	5.3%	1051	7.0%	1839	12.3%
13	749	5.0%	1023	6.8%	1772	11.8%
14	726	4.9%	919	6.1%	1645	11.0%
15	640	4.3%	860	5.7%	1500	10.0%
Total	6650	44.5%	8307	55.5%	14957	100.0%

Number (proportion) of children studied at four sites, i.e. Gujarat, Goa, Haryana, and Manipur, were 2324 (15.5%), 1939 (12.9%), 7761 (51.9%) and 2933 (19.6%), respectively. The SES was "richer" for 47.6%, "poorer" for 39.4%, and "mixed" for 13% children. Baseline characteristics are summarized in Table 2.

Prevalence of different types of HT

The overall prevalence of HT (systolic, diastolic, or both) was 23%. Systolic HT was present in 13.6%, diastolic HT in 15.3%, and both systolic and diastolic HT were present in 5.9% children. Isolated systolic HT was present in 7.7% while isolated diastolic HT was present in 9.4% (Table 2).

Univariate analysis (Table 3)

Geographic location vs prevalence of HT. The prevalence was 9.9%, 13.6%, 26.5%, and 29.9% at the four sites of Goa, Gujarat, Haryana, and Manipur, respectively ($p < 0.0001$). The prevalence was much higher at the two northern sites than the southern sites which are also closer to the ocean (see map in Figure 1).

Prevalence of HT vs age and gender. The overall prevalence of HT in boys was 20.2% and that in girls was 26.5% ($p < 0.0001$). Figure 2(a) shows the relationship of prevalence of HT with age in boys and girls. Prevalence of HT was seen to decline with age, especially in boys. From age of 5–15 years, the prevalence of HT reduced from 33% to 16.3% in boys and from 30.1% to 23% in girls.

Anthropometric parameters versus prevalence of HT. The prevalence of HT was found to be positively related to *z*-scores of height, weight, and waist ($p < 0.0001$ for each). There was also a positive relation with waist-height ratio ($p < 0.0001$) and body mass index ($p < 0.0001$). The relationships with various anthropometric parameters in boys and girls are shown in Figure 3. Waist *z*-score and waist height ratio have the most linear relationship with the prevalence of HT.

The prevalence of HT in normal, overweight, and obese children was 20.7%, 32.6%, and 42%, respectively ($p = 0.0001$). Figure 2(b) shows the prevalence of HT at different ages in obese and overweight children as compared with the rest. The risk was found to be highest in the obese but there was considerable overlap with overweight children.

Socio-economic factors versus prevalence of HT. Analyzing for socio-economic status, the prevalence of HT was 29.9%, 19%, and 9.9% in richer, poorer, and mixed groups, respectively ($p < 0.0001$). Figure 2(c) shows the prevalence of HT in each of these three groups to be consistently different at most ages.

Season versus prevalence of HT. The prevalence of HT was higher (29.4%) in the group whose BP was measured in winter (October–March) as compared with those where it was measured in summer (April–September) months (18.7%; $p < 0.0001$). Figure 2(d) shows the prevalence of HT to start rising at the end of summer, reaching a peak in the first two months of the year, with a smaller rise during the peak of summer as well. This pattern is seen in both boys and girls.

Table 2. Baseline characteristics and prevalence of hypertension.

Parameter	Mean ± SD	*n*	%
Age (completed years)	10.8 ± 2.8	14,957	
Age group			
9–12 years		6283	42.0%
<9 years		3757	25.1%
>12 years		4917	32.9%
Gender			
Female		6650	44.5%
Male		8307	55.5%
Site			
Goa		1939	13.0%
Gujarat		2324	15.5%
Haryana		7761	51.9%
Manipur		2933	19.6%
Socio-economic status			
Richer		7122	47.6%
Poorer		5896	39.4%
Mixed		1939	13.0%
Weight (kg)	31.5 ± 11.8		
Height (cm)	136.7 ± 16.6		
Body mass index (BMI)	16.3 ± 3.1		
Waist (cm)	55.0 ± 9.8		
Waist/height ratio	0.4 ± 0.05		
Weight group			
Normal		12,696	84.9%
Overweight		1501	10.0%
Obese		760	5.1%
Season			
Summer		8884	59.4%
Winter		6073	40.6%
Pulse rate	89.3 ± 14.4		
Systolic pressure	108 ± 12.3		
Diastolic pressure	68.6 ± 9.8		
Hypertension (systolic or diastolic)		3443	23.0%
Systolic hypertension		2036	13.6%
Diastolic hypertension		2289	15.3%
Both systolic and diastolic hypertension		882	5.9%
Isolated systolic hypertension		1154	7.7%
Isolated diastolic hypertension		1407	9.4%

SD: standard deviation.

Multiple regression analysis

Since waist circumference was not recorded at one site (Gujarat), multiple regression analysis was performed both excluding and including this variable. Age, gender, site, SES, height, weight, and season were other predictor variables in the model. Height and weight were divided by 10 to obtain odds ratios for each 10-unit change in parameter. For similar reasons, waist circumference was divided by five.

In the first analysis without waist circumference, complete data was available for 14,957 children from all four sites (Figure 4(a)). Age, male gender, lower SES, sites of Goa and Gujarat were independently associated with lower risk while weight, site of Manipur, and winter season were independent predictors of a

Table 3. Univariate analysis for relation between prevalence of hypertension and different parameters.

Variable	Mean (SD) for numeric variables		ORs for categorical variables			
	Normotensive group	Hypertensive group	OR	Lower 95% CI	Upper 95% CI	p Value
Age	10.89 (2.82)	10.39 (2.85)				<0.0001
Male gender			0.7	0.65	0.76	<0.0001
Site (four sites)			[a]			<0.0001
Socio-economic status (three groups)			[a]			<0.0001
Height z-score	−0.06 (0.98)	0.21 (1.01)				<0.0001
Weight z-score	−0.09 (0.93)	0.32 (1.14)				<0.0001
Waist z-score	−0.08 (0.94)	0.26 (1.11)				<0.0001
Waist/height ratio (WHR)	0.4 (0.05)	0.41 (0.06)				<0.0001
Body mass index (BMI)	16.07 (2.99)	17.01 (3.43)				<0.0001
Obese			2.56	2.21	2.98	<0.0001
Obese or overweight			2.13	1.93	2.34	<0.0001
Winter season			1.81	1.68	1.96	<0.0001

CI: confidence interval; OR: odds ratio.
[a]OR not shown since multiple categories present.

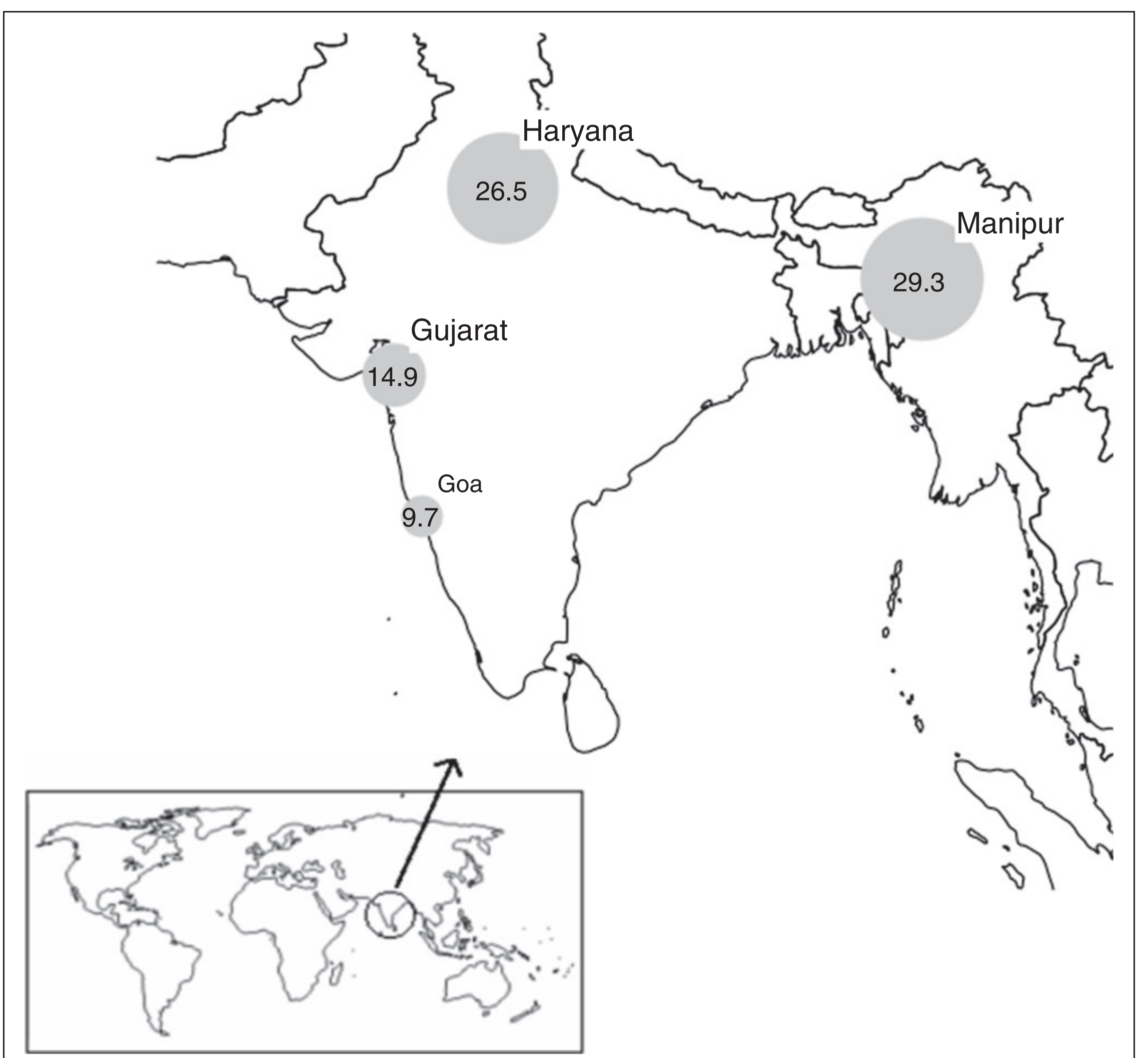

Figure 1. Map of India showing prevalence of hypertension at different locations. Circle sizes are proportional to prevalence.

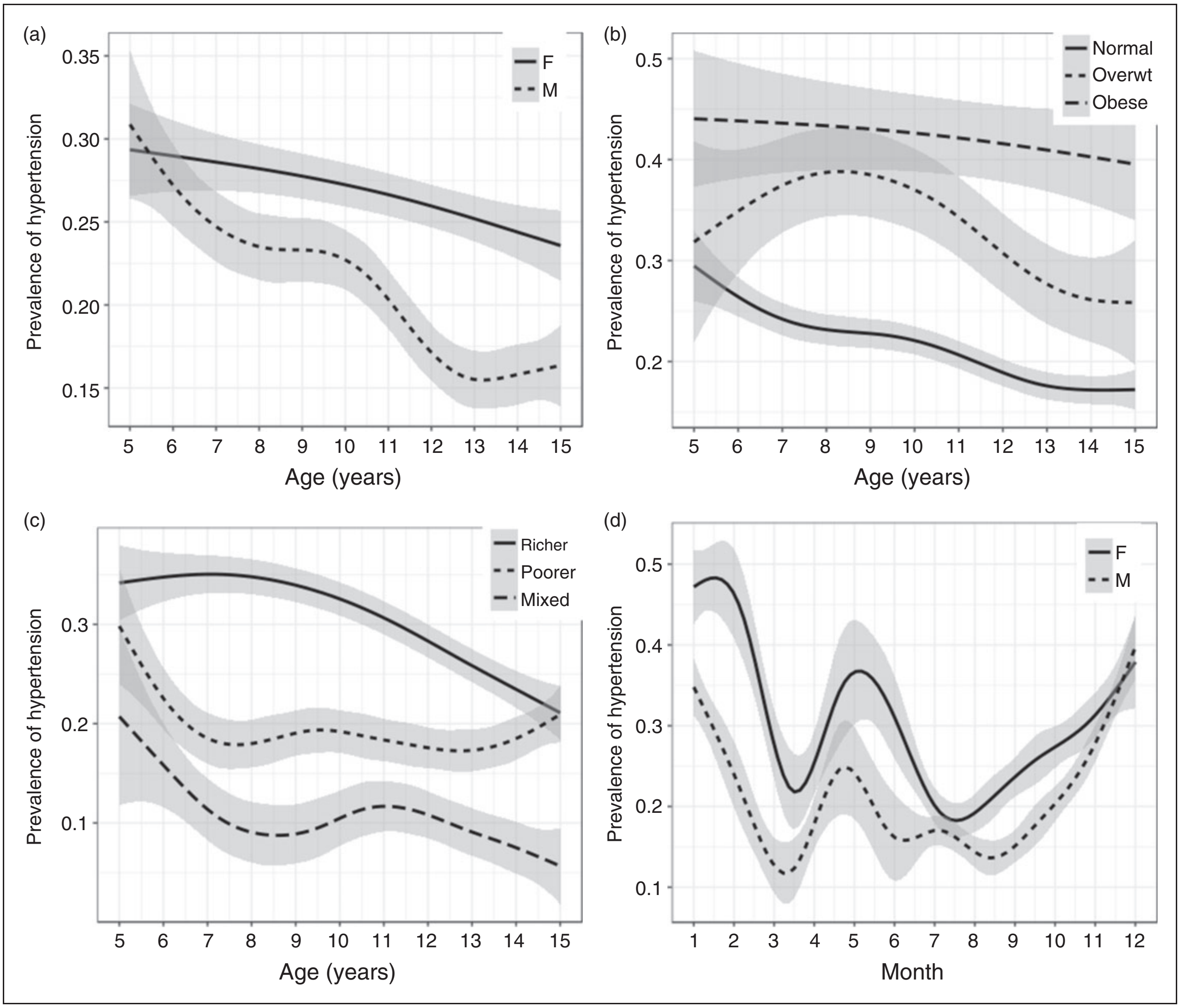

Figure 2. Relationship of prevalence of hypertension (prevHT) with (a) age and gender, (b) age and overweight/obese status, (c) age and socio-economic status and (d) month of the year in boys and girls. Shaded areas indicate 95% confidence intervals around locally weighted scatterplot smoothing or local regression (LOESS) lines. F: female; M: male.

higher risk of HT. The value of p was < 0.0001 for all these except for lower SES ($p = 0.002$). For height the value of p was of borderline significance ($p = 0.047$).

In the second analysis which included waist circumference, complete data was available for 12,068 children from three sites. The same predictor variables as above were taken in addition to waist. Higher age, male gender, and site of Goa were independently associated with a lower risk of HT while weight, waist, and winter season were independently associated with increased risk of HT. The odds ratios are shown in Figure 4(b).

Discussion

Bassareo et al. called pediatric HT a ''burning problem'' and emphasized that management of HT in children should be considered a preventive measure (p. 257).[16] The problem of obesity HT in children has reached epidemic proportions in the western world and is rising rapidly in the developing world.[9] A disturbingly high cumulative incidence of HT has been reported in Chinese children (50.1% and 70% in overweight and obese children, respectively).[11] A major finding of our study is also a high prevalence of HT amongst Indian children. Studies on newer aspects of HT in children, such as the relation to adult-derived genetic BP scores, prenatal exposure to maternal stress, and the effect of traffic-related air pollution, are also being reported.[17–19]

Highly significant associations ($p < 0.0001$) found in our univariate analysis are likely related to the large sample size of this study. A significant variation of

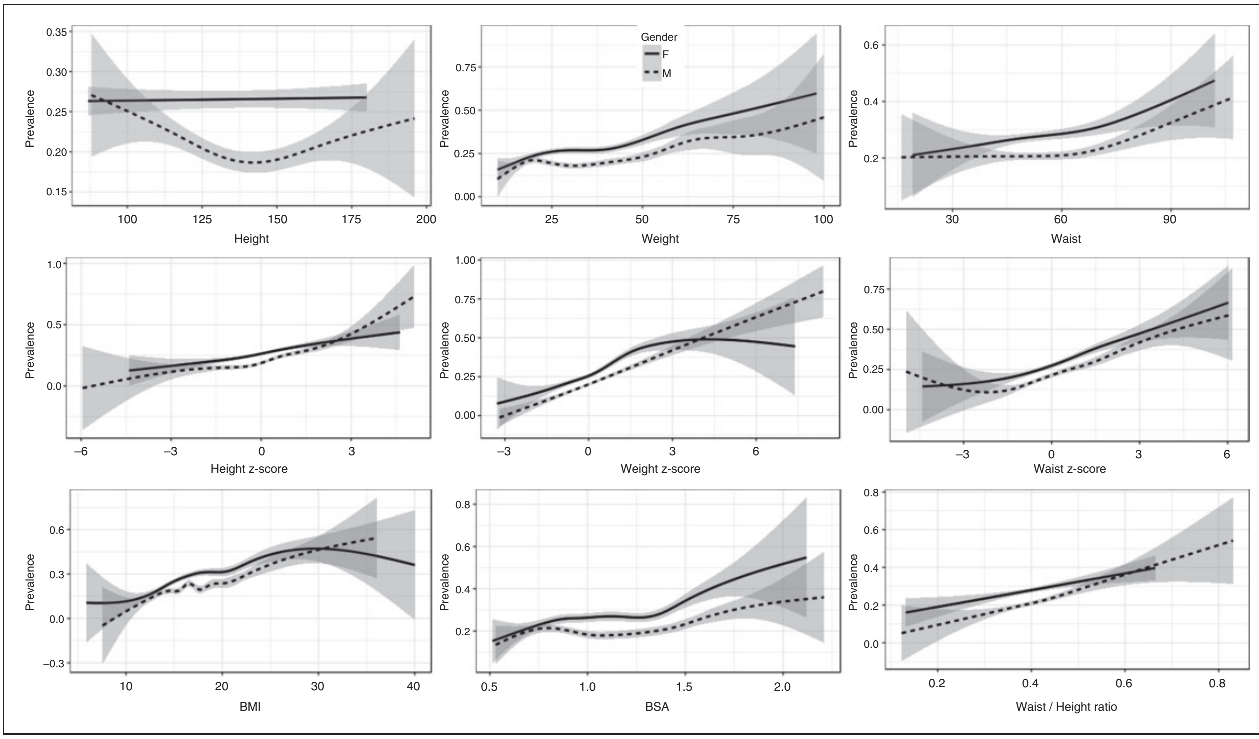

Figure 3. Relation between various anthropometric parameters and prevalence of hypertension in boys and girls. Parameters are (from left to right and top to bottom) height, weight, waist circumference, height z-score, weight z-score, waist z-score, body mass index (BMI), body surface area (BSA), and waist/height ratio. Shaded areas indicate 95% confidence intervals around locally weighted scatterplot smoothing or local regression (LOESS) lines. F: female; M: male.

the prevalence of HT between different geographical locations was observed. This variation could be due to local diet (especially salt intake) as well as other environmental factors (including temperature, humidity, exercise habits etc.). The prevalence was higher at two sites which are located more in the north and have lower ambient temperatures over the year. The two sites with lower prevalence are also closer to the ocean, where higher humidity could cause increased perspiration and hence salt and water loss from body. Additionally, ethnic variation and genetic factors could also be important.

Contrary to expectation, we found the prevalence to be higher in younger children and in females, though this has been observed in other studies as well.[10,20] The prevalence of HT at the upper end of our age group could be affected by the onset of puberty, though we did not study this aspect.

A clear relationship between anthropometric variables and the prevalence of HT found in our study is consistent with earlier reports. Multiple regression analysis including waist circumference showed that weight, and to a lesser extent waist, were independent predictors, while height was not. Our data strengthens the evidence that obesity is an important risk factor for the prevalence of HT. The association of richer SES with higher prevalence of HT was also expected. Since this relationship is independent of obesity in our analysis, other factors such as psychosocial stress and greater intake of salt and processed foods in the higher SES group could be contributing mechanisms.

There was a significant association of prevalence of HT with season of the year, and higher prevalence was found in winter months. Increase of BP in winter months has also been reported in several earlier studies.[21–23] It is most likely due to increased salt and water loss with perspiration during hot weather that occurs during the summer months in most parts of the country.

Measurement of BP on a single day raises the possibility that the prevalence observed in our study represents a falsely high value. Chiolero et al. found the prevalence to be lower if measurements were repeated over a period of a few weeks.[24] The possibility of overestimation of the prevalence of HT was also highlighted by Wirix et al.[25] Another confounding factor could be using the 50th percentile of height values for all children to classify HT using Fourth report tables. However, a number of reports have stressed the need for simplification of the current definition of HT for children.[26–29] A recent update of

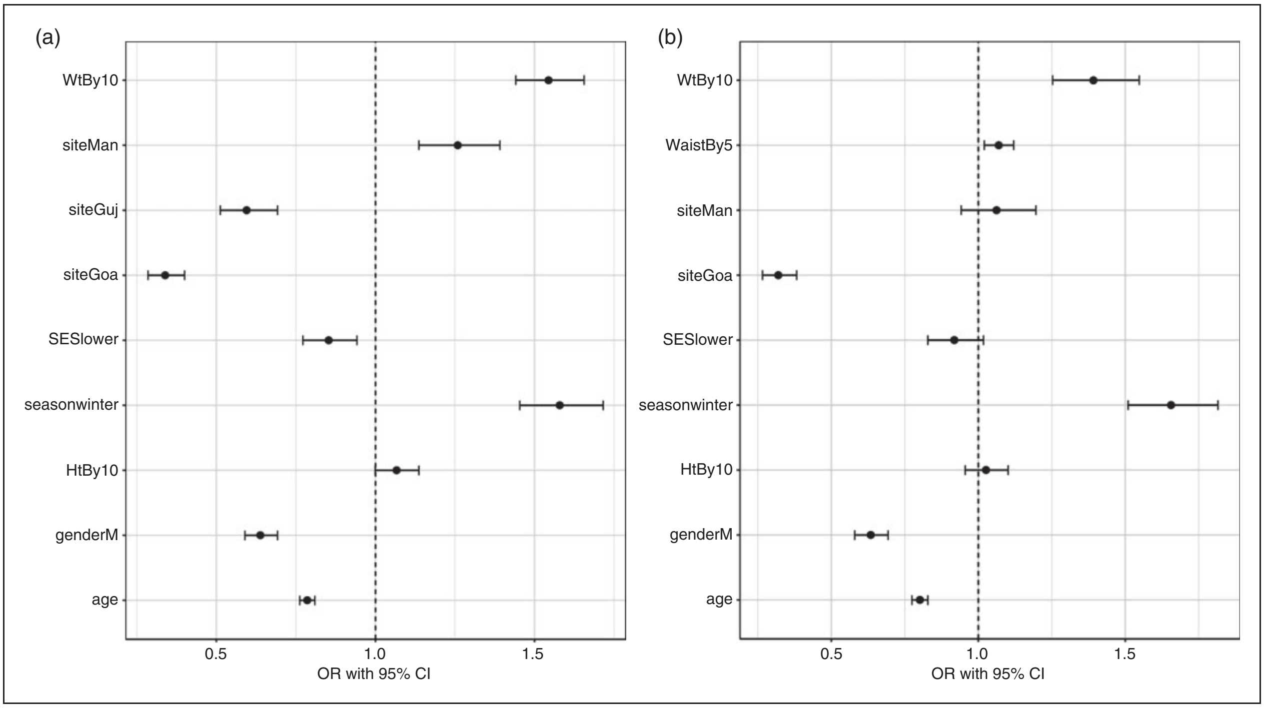

Figure 4. Forest plot of odds ratios (ORs) from multiple regression analysis performed (a) without and (b) with waist circumference in model. Age, gender, winter season, Goa site, and weight are significant and independent predictors of hypertension in both models. Waist was significant predictor in second model. Height was of border significance in first and not significant in the second model. Lower socio-economic status (SES), Gujarat (Guj) and Manipur (Man) sites were significant predictors in one model only. For numeric parameters, ORs are shown for one-year change in age, 5 cm change in waist circumference and 10 cm change in height or weight. CI: confidence interval.

the Fourth report has also included a simplified screening BP table based on age and gender only.[30]

The high prevalence of HT seen in our study also raises the possibility that Fourth report definition (which is based on children in different areas of the USA) may not be applicable to Indian children. Normative data is being reported from different parts of the world.[31–35] A recently published update to the Fourth report has thresholds which are generally, though slightly, even lower.[30] There have also been attempts to develop a more representative international definition.[1]

There are many studies supporting the association of childhood HT with cardiovascular risk in adulthood. Chen et al. documented evidence of BP tracking from childhood into adulthood in a meta-regression analysis.[4] Theodore et al. found that preHT and HT in childhood are associated with the development of more cardiovascular risk factors over time and predict adult cardiovascular risk.[5] In the Bogulosa Heart Study, Berenson et al. showed an association between multiple cardiovascular risk factors and atherosclerosis in children and young adults.[8] In addition, systolic BP was found to an independent predictor of arterial stiffness in young adults, providing evidence that target organ damage also occurs as a result of childhood HT.[8] In a recent further analysis, they reported BP trajectories from childhood to adult life and found puberty to be a critical stage in development of adult HT.[36] Systolic BP was also one of the predictors of carotid artery intima-media thickness (CIMT) in the Cardiovascular Risk in Young Finns Study.[6] Similarly, in the International Childhood Cardiovascular Cohort Consortium study, of 4210 subjects, individuals with persistently elevated BP were found to be at higher risk of carotid atherosclerosis, as measured directly by CIMT, than those in whom high BP in childhood had resolved by adulthood.[37] The difference persisted after controlling for age, gender, adiposity, and definition of HT used. Hence, there is a great deal of evidence that elevated BP in childhood causes target organ damage and an active approach to screening and managing childhood HT is likely to be rewarding.

We have recorded blood pressure twice only in children in whom the first reading was high. It is possible that the prevalence may be higher if the mean of two recordings was taken for all children, as recommended by some published guidelines.[38–40]

Conclusions

Even in the predominantly rural populations of India, the prevalence of HT is high in childhood. Both systolic and diastolic HT are common. Richer SES, high weight (obesity), and increased waist circumference (abdominal obesity) are important independent predictors and efforts should be made to contain the obesity epidemic. The relationship of higher risk of HT with lower age, female gender, certain geographical locations, and winter months needs further studies for confirmation and to clarify underlying pathogenetic mechanisms. Factors identified in this study can help plan cost-effective strategies of screening and management programs to control this widespread public health problem.

Acknowledgements

The authors thank the administration and staff of all the participating schools in the conduction of the study. The contribution of the parents and children who underwent the screening is deeply appreciated.

Author contribution

AS and SR contributed to the conception or design of the work. RN, AnD, RST, SK, KN, AKJC, AmD, and RS contributed to the acquisition, analysis, or interpretation of data for the work. RN and AS drafted the manuscript. AnD and JC critically revised the manuscript. All authors gave final approval. RN, AS, AnD, SR, RST, and SK agree to be accountable for all aspects of work ensuring integrity and accuracy.

Declaration of conflicting interests

The authors declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The authors disclosed receipt of the following financial support for the research, authorship, and/or publication of this article: The study was funded by restricted research grant from Medtronics Foundation, USA (through Public Health Foundation of India (PHFI), grant number: F087) and Indian Council of Medical Research, India (grant number: 5/4/1-14/09-NCD-II). The sponsors had no role in design of study; collection, analysis, or interpretation of the data; or writing of the manuscript and in the decision to submit the paper for publication. The corresponding author had full access to all the data in the study and takes final responsibility for the decision to submit for publication.

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