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ORIGINAL ARTICLE

Body mass index trend and its association with blood pressure distribution in children

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The aim of the study was to examine the association of a trend in body mass index (BMI) status with current blood pressure in a cohort of school children from South India. A population of 25 228 children was selected using stratified random sampling method. Height and weight were measured in 2003–2004. Height, weight and blood pressure were measured in 2005–2006. A total of 12 129 children aged 5–16 years having paired data were analysed. Blood pressure and BMI values were converted to *Z* scores using International paediatric reference values. An increase in *Z* BMI meant that the child is moving to a higher BMI level with respect to his or her age and sex. In the cohort, 62.4% children had a higher *Z* BMI at follow-up than at baseline. Children with higher *Z* BMI at follow-up were labelled as positive BMI status group (PBSG) and the remaining as negative BMI status group (NBSG). The positive trend in BMI was more in rural areas, government schools and girls. In all subgroups, PBSG showed significantly higher systolic blood pressures (SBPs) than NBSG. PBSG showed significantly higher diastolic blood pressures (DBPs) in urban area, government schools and girls when compared with NBSG. Prevalence of first instance systolic hypertension was more in PBSG in all the subgroups except in rural children. Prevalence of diastolic hypertension was significantly higher in PBSG in urban subgroup only. BMI status trends are associated with blood pressure distribution in children.
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Introduction

Childhood obesity is currently exhibiting a rapid growth pattern across the globe. The global paediatric population afflicted with obesity is expected to double in 2010 when compared with the figures available for the last decade of the previous century.[1] Studies from developing economies like India and China have shown rates faster than these global estimates.[2,3] Childhood obesity is known to persist into adulthood.[4] Obesity is well documented as a major contributor to cardiovascular risk in the population.[5]

Cardiovascular risk factor levels are strongly related to weight status and fat distribution in children.[6] Prevalence of hypertension in overweight children underline the role of adiposity in increasing blood pressure in children.[3,7–9] There is evidence of a concordant increase in body mass index (BMI) and systolic blood pressure (SBP) among adolescents and children.[10] Excessive BMI gain at any life stage is known to be associated with higher blood pressure in later life.[11] Thinner children are more vulnerable to BMI gain and increased blood pressure in adulthood.[11] The positive influence of adiposity on blood pressure is evident even in normal weight children, suggesting that this problem is not restricted to the overweight children.[12] Sociodemographic factors like socioeconomic levels and urbanization strongly influence the adiposity levels in populations.[2,3,13] The Indian population is currently experiencing a demographic, epidemiological and nutritional transition resulting in increasing burden of chronic diseases and obesity.[14] It is possible that all these factors that influence childhood obesity trends will have a similar influence on blood pressure distribution in children. Excessive gains of BMI during childhood resulting in higher *Z* BMI have clinical implications. BMI values are usually converted to *Z* scores using mean and s.d. derived from reference populations. This conversion helps in comparing various populations. An increase in *Z* BMI implies that the child is moving to a higher BMI level with respect to his/her age and sex.

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Considering the role of BMI in increasing cardiovascular risk, this could mean a worsening of cardiovascular fitness due to unfavourable adiposity levels. Z BMI trends could be used for prediction and monitoring of changes in cardiovascular risks factors among children.

The aim of this study was to examine the association of a trend in BMI status with current blood pressure in a cohort of school children from a selected population in South India. The secondary aim was to examine the role of sociodemographic factors in modifying the association of BMI status trend with blood pressure.

Methods

A population of $\sim$1.37 million was selected from a contiguous area in Ernakulam district, Kerala, South India. Stratified random sampling method was used for sample selection. Schools in the area were stratified into five groups according to their student strength and a representative sample of 46 schools with a cumulative population of 25 228 children was randomly chosen. Height and weight were recorded for 24 842 children of age group 5–16 years in 2003–2004. Height, weight and blood pressure were recorded for 20 263 children in 2005–2006 from the same study population. All measurements were recorded in the school premises by seven observers who were recruited and trained specifically for the study. All seven observers were present for each of the 46 school surveys. Blood pressure was measured using mercury sphygmomanometer and as recommended by The Fourth Report on the diagnosis, evaluation and treatment of high blood pressure in children and adolescents.[15] Blood Pressure was measured in a sitting posture with the subject's right hand resting on the examining table. The cubital fossa of the right hand was positioned and supported at heart level. Chairs of adequate height were used for various groups. The stethoscope was placed over the brachial artery pulse, proximal and medial to the cubital fossa and below the bottom edge of the cuff (that is about 2 cm above the cubital fossa). Cuffs having a bladder width that is $\sim$40% of the arm circumference midway between the olecranon and the acromion were used. The BP measurement was taken at the right arm for consistency and comparison with the standard tables. Three readings of blood pressures of each child were taken at an interval of 2 min each. Mean of three readings of the blood pressure of each child was taken for analysis. A cohort of 12 129 children having two sets of anthropometric measurements, one in 2003–2004 and the other in 2005–2006 was identified for this study. The reference data used to derive the Z scores of BMI were taken from Centre for Disease Control and Prevention 2000 data set for BMI in children and adolescents.[16] Children with higher Z BMI at follow-up were labelled as positive BMI status group (PBSG) and the remaining as negative BMI status group (NBSG). Average systolic (SBP) or diastolic blood pressure (DBP) $\geqslant$95th percentile for gender, age and height was considered as first instance hypertension.[15] Blood pressure values were converted to Z scores using the reference mentioned above.

The cohort was divided into various subgroups for detailed analysis. Schools were divided into government and private schools. Government schools receive subsidies from the educational department enabling them to provide education at less than INR 500 per year per student (approximately US$ 12). Private schools receive no subsidies and charge students INR 5000 and above per year. Schools were also divided into rural and urban as well. Rural area was defined if $>$75% of adult male population was engaged in agricultural occupations along with lower levels of developmental indices. Non-rural areas were designated as urban areas. Further details of the methodology is available in the previous publication.[3]

Statistical analysis

The data were analysed using SPSS software version 15.0. The difference in mean Z scores of blood pressures between subgroups were analysed by independent sample t-test. The difference in prevalence of hypertension was analysed by Pearson χ^2 test. Significance was assumed for P-values $<$0.05.

Ethical approval

Approval for the study was obtained from the ethical committee of the home institution in compliance with the guidelines issued by Indian Council of Medical Research. Consent to conduct the school survey and blood pressure measurement of the students was obtained from parents through school authorities. Verbal assent was taken from the children after demonstrating and explaining the procedure for blood pressure measurement.

Results

Descriptive data of the cohort based on the two periods 2003–2004 and 2005–2006 are given in Table 1. The mean BMI Z scores for the cohort in 2003–2004 and 2005–2006 were -0.80 and -0.67, respectively. This difference was statistically significant ($P<0.001$). Out of the total 12 129 children, 7566 (62.4 %) showed an increase in BMI Z score at follow-up when compared with baseline. The positive trend in BMI status was more visible in rural area compared with urban area (63.5 vs 61.5%, $P=0.027$), government schools compared with private schools (64.5 vs 55.2%, $P<0.001$) and girls compared with boys (63.9 vs 60.7%, $P<0.001$).

Table 1 Descriptive data of the study cohort

Age (years)	Boys				Girls			
	N	Height (cm)	Weight (kg) Mean	BMI (kg m^{-2})	N	Height (cm)	Weight (kg) Mean	BMI (kg m^{-2})
2003								
5.00–5.99	293	109.7 (4.6)	16.7 (2.2)	13.8 (1.3)	223	108.6 (5.5)	16.3 (2.4)	13.8 (1.5)
6.00–6.99	580	115.5 (5.4)	19.1 (3.2)	14.2 (1.6)	486	114.3 (5.5)	18.6 (3.5)	14.2 (1.8)
7.00–7.99	574	120.7 (6.2)	21.1 (4.1)	14.4 (1.9)	425	120.2 (5.8)	20.8 (3.8)	14.3 (1.8)
8.00–8.99	534	126.6 (6.1)	23.8 (4.6)	14.8 (2.0)	421	125.5 (6.4)	23.4 (5.3)	14.7 (2.2)
9.00–9.99	720	131.9 (6.5)	26.4 (6.0)	15.1 (2.3)	737	131.4 (6.5)	26.4 (5.6)	15.1 (2.3)
10.00–10.99	812	135.9 (6.8)	28.5 (6.9)	15.3 (2.6)	946	136.5 (7.1)	28.8 (6.2)	15.3 (2.3)
11.00–11.99	733	140.5 (7.4)	31.2 (7.5)	15.6 (2.7)	1059	142.3 (7.1)	32.7 (7.1)	16.0 (2.6)
12.00–12.99	842	145.9 (7.4)	33.9 (7.4)	15.8 (2.5)	1122	147.9 (7.2)	36.7 (8.1)	16.6 (2.8)
13.00–13.99	556	152.5 (8.7)	39.2 (9.8)	16.7 (3.0)	706	151.0 (6.7)	39.7 (7.7)	17.3 (2.7)
14.00–14.99	197	155.9 (8.7)	41.6 (9.7)	17.0 (2.9)	146	151.9 (6.1)	40.9 (7.3)	17.7 (2.7)
2005								
7.00–7.99	207	122.4 (5.1)	21.3 (3.8)	14.1 (1.8)	163	122.1 (5.7)	21.6 (5.1)	14.4 (2.4)
8.00–8.99	592	127.4 (5.8)	24.5 (5.2)	15.0 (2.3)	489	126.1 (6.3)	23.7 (4.9)	14.8 (2.1)
9.00–9.99	574	131.8 (6.5)	26.8 (5.9)	15.3 (2.4)	454	131.7 (6.6)	26.6 (5.7)	15.2 (2.3)
10.00–10.99	551	137.5 (6.8)	30.1 (6.8)	15.8 (2.6)	406	138.0 (7.2)	30.6 (7.4)	15.9 (2.7)
11.00–11.99	746	142.5 (7.5)	33.3 (8.1)	16.2 (2.8)	763	143.7 (7.4)	34.4 (8.2)	16.5 (2.8)
12.00–12.99	837	146.7 (8.0)	35.9 (9.2)	16.5 (3.0)	989	148.7 (6.6)	38.4 (8.3)	17.2 (2.9)
13.00–13.99	754	153.7 (8.7)	40.7 (9.4)	17.1 (2.9)	1034	152.0 (6.0)	41.4 (7.5)	17.9 (2.8)
14.00–14.99	836	160.1 (8.2)	45.0 (9.4)	17.4 (2.7)	1204	154.5 (5.8)	44.1 (8.6)	18.4 (3.1)
15.00–15.99	537	164.3 (7.4)	49.3 (10.0)	18.2 (2.9)	648	155.2 (6.3)	45.9 (8.4)	19.0 (2.9)
16.00–16.99	211	166.1 (6.7)	52.7 (10.7)	19.0 (3.2)	131	155.3 (6.4)	46.2 (8.4)	19.1 (3.1)

Values in parentheses are s.d.

The mean *Z* BMI of NBSG children decreased from –0.57 (0.94) in 2003 to –0.86 (0.84) in 2005, whereas that of PBSG children increased from –0.94 (0.80) to –0.55 (0.89) in the same period. Similar trends were noted for PBSG and NBSG children in all the subgroups (Table 2). The differences in *Z* BMI between the two time points for PBSG and NBSG children were significant in the cohort as well as in all the subgroups ($P<0.001$).

The mean *Z* scores for SBP and DBP of the cohort were 0.25 and 0.70, respectively. Significant differences were noted for SBP in rural urban (0.27 vs 0.22, $P=0.004$), government private (0.29 vs 0.09, $P<0.001$) and boys girls (0.08 vs 0.40, $P<0.001$) comparisons. Significant differences were also noted for DBP in rural urban (0.73 vs 0.68, $P=0.001$), government private (0.74 vs 0.58, $P<0.001$) and boys girls (0.64 vs 0.77, $P<0.001$) comparisons as well.

The mean *Z* score of SBP was higher for PBSG children than for NBSG children in the cohort (0.30 vs 0.15, $P<0.001$). In all subgroups, the PBSG children had significantly higher mean *Z* score of SBP when compared with NBSG children (Table 2). The mean *Z* score of DBP was higher for PBSG children than for NBSG children in the cohort (0.72 vs 0.65, $P<0.001$). Even though the PBSG children had higher mean *Z* score of DBP when compared with the NBSG children in all subgroups, statistical significance of the difference was exhibited only in children from urban and government schools as well as in girls. The intergroup comparisons of systolic and DBP with their confidence intervals are presented in Figures 1 and 2.

When the prevalence of hypertension was examined, first instance systolic hypertension was significantly higher in PBSG children than in NBSG children (7.61 vs 5.59%, $P<0.001$). The details of subgroup analysis are available in Table 3. All subgroups showed significantly higher prevalence of first instance systolic hypertension in PBSG children than in NBSG children except in rural subgroup. There was no significant difference in prevalence of first instance diastolic hypertension between PBSG and NBSG in the total sample. The same trend was seen in all subgroups except in urban subgroup.

The sample was divided into four quartiles based on *Z* BMI difference as well as *Z* BMI at follow-up (Table 4). This was done to assess the dose–response effect of *Z* BMI change as well as *Z* BMI at follow-up on systolic and DBP. The analysis demonstrated that there exists a linear correlation for mean *Z* BMI difference with mean *Z* SBP ($R^2=0.98$, $P=0.012$) and mean *Z* DBP ($R^2=0.97$, $P=0.017$). The analysis also demonstrated a linear correlation for mean *Z* BMI at follow-up with mean *Z* SBP ($R^2=0.68$, $P=0.176$) and mean *Z* DBP ($R^2=0.53$, $P=0.274$).

Table 2 Comparison of mean Z scores of blood pressure in relation to BMI status trends

		n	Z BMI 03 Mean	Z BMI 05 Mean	Z SBP 05 Mean	Z DBP 05 Mean
All	G1	4563	−0.57 (0.94)	−0.86 (0.84)	0.15 (0.95)	0.67 (0.72)
	G2	7566	−0.94 (0.80)	−0.55 (0.89)	0.30 (0.95)	0.72 (0.72)
	Sig				<0.001	<0.001
Rural	G1	1913	−0.78 (0.79)	−1.05 (0.70)	0.21 (0.96)	0.72 (0.73)
	G2	3327	−1.07 (0.70)	−0.71 (0.78)	0.31 (0.95)	0.73 (0.72)
	Sig				<0.001	0.727
Urban	G1	2650	−0.41 (1.00)	−0.72 (0.90)	0.11 (0.94)	0.63 (0.72)
	G2	4239	−0.84 (0.86)	−0.43 (0.95)	0.30 (0.94)	0.72 (0.71)
	Sig				<0.001	<0.001
Govt	G1	3321	−0.75 (0.80)	−1.01 (0.71)	0.20 (0.95)	0.71 (0.72)
	G2	6037	−1.04 (0.72)	−0.67 (0.80)	0.34 (0.96)	0.76 (0.71)
	Sig				<0.001	0.005
Private	G1	1242	−0.09 (1.10)	−0.44 (1.00)	0.01 (0.91)	0.56 (0.73)
	G2	1529	−0.53 (0.98)	−0.10 (1.06)	0.15 (0.90)	0.59 (0.73)
	Sig				<0.001	0.326
Boys	G1	2295	−0.61 (0.98)	−0.91 (0.87)	0.00 (0.89)	0.62 (0.71)
	G2	3552	−0.99 (0.85)	−0.58 (0.95)	0.13 (0.90)	0.65 (0.71)
	Sig				<0.001	0.080
Girls	G1	2268	−0.53 (0.89)	−0.80 (0.81)	0.31 (0.98)	0.73 (0.74)
	G2	4014	−0.90 (0.76)	−0.53 (0.82)	0.46 (0.96)	0.79 (0.72)
	Sig				<0.001	0.002

Abbreviations: DBP, diastolic blood pressure; Govt, government schools; G1, negative BMI status trend group (NBSG); G2, positive BMI status trend group (PBSG); SBP, systolic blood pressure; Sig, significance.
Values in parentheses are s.d.

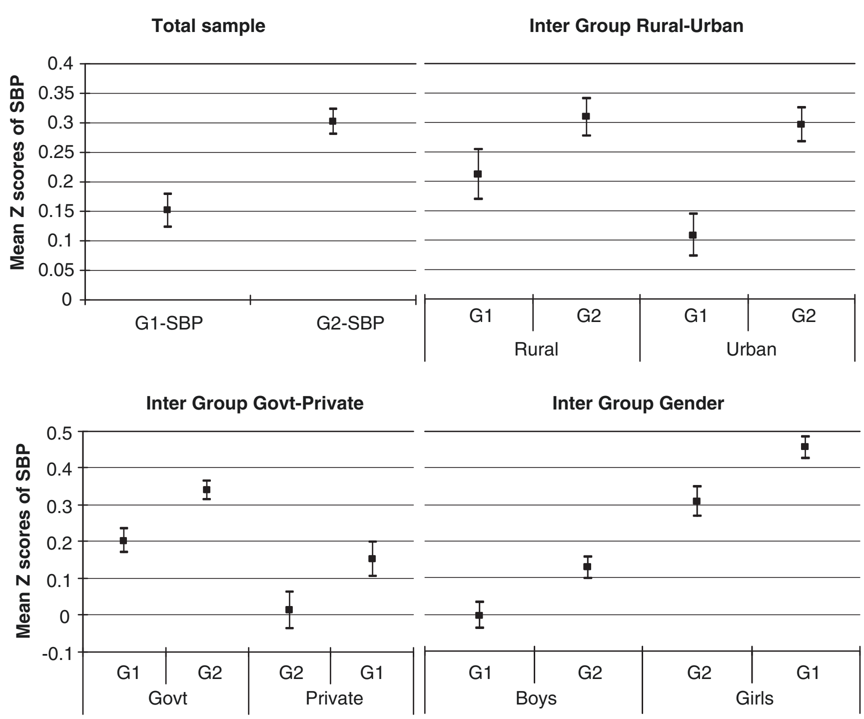

Figure 1 Comparison of mean Z scores of systolic blood pressure between groups.

Discussion

From the results, it is evident that the population shift in BMI is towards the reference population. The shift towards reference population seems to be more in the case of children from rural area and government schools as well as in girls. The cohort seems to express significantly higher SBP and DBP

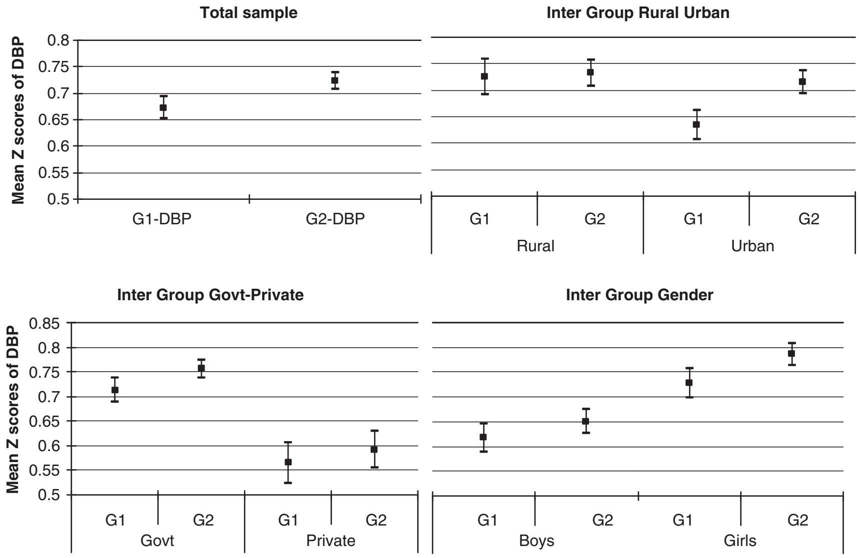

Figure 2 Comparison of mean *Z* scores of diastolic blood pressure between groups.

Table 3 Prevalence of first instance hypertension in relation to BMI status trends

Subgroups		*Systolic blood pressure*		*Diastolic blood pressure*	
		Normal	*HT*	*Normal*	*HT*
Rural	Group-1	1791 (93.6)	122 (6.4)	1754 (91.7)	159 (8.3)
	Group-2	3084 (92.7)	243 (7.3)	3083 (92.7)	244 (7.3)
		$P=0.205$		$P=0.201$	
Urban	Group-1	2517 (95.0)	133 (5.0)	2505 (94.5)	145 (5.5)
	Group-2	3906 (92.1)	333 (7.9)	3936 (92.9)	303 (7.2)
		$P<0.001$		$P=0.006$	
Govt	Group-1	3100 (93.4)	221 (6.7)	3065 (92.3)	256 (7.7)
	Group-2	5533 (91.7)	504 (8.4)	5561 (92.1)	476 (7.9)
		$P=0.003$		$P=0.761$	
Private	Group-1	1208 (97.3)	34 (2.7)	1194 (96.1)	48 (3.9)
	Group-2	1457 (95.3)	72 (4.7)	1458 (95.4)	71 (4.6)
		$P=0.007$		$P=0.315$	
Boys	Group-1	2225 (97.0)	70 (3.1)	2183 (95.1)	112 (4.9)
	Group-2	3390 (95.4)	162 (4.6)	3348 (94.3)	204 (5.7)
		$P=0.004$		$P=0.154$	
Girls	Group-1	2083 (91.8)	185 (8.2)	2076 (91.5)	192 (8.5)
	Group-2	3600 (89.7)	414 (10.3)	3671 (91.5)	343 (8.6)
		$P=0.005$		$P=0.914$	

Abbreviation: Govt, government schools.
Values in parentheses are percentages. Group-1 denotes negative BMI status trend group (NBSG). Group-2 denotes positive BMI status trend group (PBSG). HT denotes first instance hypertension.

compared with the reference values, which are from a multiethnic western population (USA). The difference seems to be more in case of DBP than SBP. The role of socioeconomic factors in modifying the population distribution of blood pressure is well documented by the results. Both SBP and DBP were noted to be higher in children from rural areas, government schools and in girls. Current medical literature prompts us to expect higher blood pressures in socioeconomically higher populations as

Table 4 Blood pressure distribution across quartiles of *Z* BMI difference and *Z* BMI at follow-up

Quartile	*Quartiles according to Z BMI difference*					
	Z BMI difference		*Z SBP*		*Z DBP*	
	Mean	*s.d.*	*Mean*	*s.d.*	*Mean*	*s.d.*
1	−0.40	0.32	0.15	0.94	0.66	0.73
2	0.00	0.07	0.20	0.94	0.70	0.72
3	0.23	0.07	0.27	0.96	0.71	0.71
4	0.70	0.39	0.37	0.94	0.74	0.72
	Quartiles according to Z BMI at follow-up					
	Z BMI at follow-up		*Z SBP*		*Z DBP*	
1	−1.56	0.24	0.02	0.91	0.65	0.71
2	−1.06	0.12	0.15	0.93	0.67	0.73
3	−0.59	0.16	0.31	0.94	0.73	0.71
4	0.53	0.79	0.50	0.94	0.77	0.72

Abbreviations: SBP, systolic blood pressure; s.d., standard deviation; DBP, diastolic blood pressure.

well as in populations more exposed to urbanization. This study differs from these viewpoints. The study suggests that blood pressure is more in rural areas and government schools, both surrogates of low levels of urbanization and socioeconomic status respectively. A large epidemiological study from China reported significantly higher SBP and DBP in rural children compared with their urban counterparts.[17] Children from poorer socioeconomic positions have earlier shown higher risk of hypertension in adulthood.[18] In addition, there is evidence from earlier studies to suggest that poor socioeconomic status of parents can predict significantly higher SBP and DBP for their children during adulthood.[19,20] Possible reasons for this contrasting pattern of higher blood pressures in less urbanized and socioeconomically deprived populations could be the role of *in utero* as well as early life nutritional influences as suggested by earlier studies.[11,21]

When the cohort as a whole was analysed, PBSG children showed significantly higher SBP and DBP than NBSG children. Subgroup analysis revealed that the difference in SBPs between PBSG and NBSG children were significant in all the subgroups. In contrast, the differences in DBPs between PBSG and NBSG children were significant only in urban, government and girls subgroups. Combining the two observations, it seems that the association of BMI status trend is stronger with SBP than with DBP. The protective effect of a recent, negative trend of BMI status in case of SBP can be expected irrespective of socioeconomic and gender differences in the population. In contrast, the protective effect of a recent, negative trend of BMI status in case of DBP need not be evident across all socioeconomic and gender classifications. This observation assumes public health significance due to the fact that Indian children have a tendency to exhibit higher DBPs even from early childhood onwards.[22] It is logical to believe that populations exhibiting higher DBPs even at lower levels of BMI are more susceptible to increase in cardiovascular risk from excess weight gain. Such populations could behave differently to interventions targeting reductions in cardiovascular disease burden.

The prevalence of first instance systolic hypertension in the cohort was significantly more in PBSG children compared with NBSG children. Similar patterns were visible in all the subgroups except in the rural subgroup. The association of diastolic hypertension with BMI status trend seemed to be weak and insignificant in the cohort. Similar findings were visible in all the subgroups except in the urban subgroup.

The analysis of the quartile comparisons based on *Z* BMI difference as well as *Z* BMI at follow-up revealed a dose–response effect of both the parameters on SBP and DBP. The analysis suggests that a recent BMI status difference predicts current blood pressure status better than current BMI status.

The inability of a recent history of BMI reduction to produce significantly lower hypertension prevalence in a rural setting seems to be a public health concern. This is in contrast to the fact that the protective effect of a recent BMI reduction in urban children from the same cohort is clearly demonstrated as significantly lower prevalence of systolic as well as diastolic hypertension. In addition, if we compare the differences in blood pressure associated with change in BMI status in the rural and urban areas, it becomes clear that the range of blood pressure difference is much less in the rural area when compared with urban area (Figures 1 and 2). It is possible that there exist certain unidentified factors in the rural area that are partly opposing the beneficial effect of BMI reductions on blood pressure. It should be noted that over two thirds of the Indian paediatric population hails from rural settings and may be influenced by these unidentified factors. The early identification of these detrimental factors is of utmost importance to the future health of our rural children.

Conclusions

BMI status trends in children exhibit a strong association with SBP and DBP in childhood. The strength of this association seems to be more in the case of SBP. Sociodemographic factors seem to modify this association. The fact that socioeconomic deficiencies in childhood are associated with increased cardiovascular disease burden demands serious attention. More studies are needed to identify in detail the detrimental factors that increase cardiovascular risk in children from less privileged sections of the population.

What is known about this topic

- There is a strong association between body mass index and blood pressure in children.

What this study adds

- A trend in body mass index status is associated with current blood pressure status in children.
- This association of body mass index with blood pressure in children is modified by sociodemographic factors.

Conflict of interest

The authors declare no conflict of interest.

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