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Social class-related gradient in the association of skeletal growth with blood pressure among adolescent boys in India

Shobha Rao* and Priti Apte
Biometry and Nutrition Group, Agharkar Research Institute, G.G. Agarkar Road, Pune – 411 004, India

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Abstract

Objective: In view of the fact that height differences between socio-economic groups are apparent early in childhood, it is of interest to examine whether skeletal growth is reflective of the social class gradient in CVD risk. The present study examined blood pressure levels, adiposity and growth of adolescent boys from high and low social classes.
Design: In a cross-sectional study, skeletal growth (height and sitting height), adiposity (weight, BMI and body fat) and blood pressure levels of the adolescents were measured.
Setting: Pune, India.
Subjects: Adolescent schoolboys (9–16 years) from high socio-economic (HSE; *n* 1146) and low socio-economic (LSE; *n* 932) class.
Results: LSE boys were thin, short and undernourished (mean BMI: 15·5 kg/m^2 *v.* 19·3 kg/m^2 in HSE boys, $P = 0·00$). Social gradient was revealed in differing health risks. The prevalence of high systolic blood pressure (HSBP) was high in HSE class (10·5 % *v.* 2·7 % in LSE class, $P = 0·00$) and was associated with adiposity, while the prevalence of high diastolic blood pressure (HDBP) was high in LSE class (9·8 % *v.* 7·0 % in HSE class, $P = 0·00$) and had only a weak association with adiposity. Despite this, lower ratio of leg length to height was associated with significantly higher respective health risks, i.e. for HDBP in LSE class (OR = 1·99, 95 % CI 1·14, 3·47) and for HSBP in HSE class (OR = 1·69, 95 % CI 1·02, 2·77).
Conclusions: As stunting in childhood is a major problem in India and Asia, the leg length to height indicator needs to be validated in different populations to understand CVD risks.

Keywords
Adolescents
Leg length
Leg length to height ratio
Blood pressure

In recent years accumulating evidence has suggested that there is substantial uncertainty regarding the relationship between excess adiposity and CVD risk, both within and across populations[1]. It is reported that the prevalence of hypertension, one of the major CVD risks, is growing in India and is significantly higher in urban than rural populations. Examining the social class-related gradient in CVD risk in India may therefore help in planning appropriate preventive strategies.

Skeletal growth differentials are perhaps of importance in this context as Billewicz *et al.*[2] have shown that social class and geographical differences in height are mainly due to differences in leg length, while Gunnell *et al.*[3] have reported that apart from differentiating between socio-economic groups and environmental conditions, leg length also acts as a predictor of CHD risk. Hardy *et al.*[4] suggested that poor height growth may provide a partial explanation for the social class gradient in blood pressure through socially patterned factors such as early nutrition, infection and stress[4]. Wadsworth *et al.*[5] further highlighted the importance of different components of height, showing that leg length was sensitive to infant (under 5 years) socio-economic circumstances and diet while trunk length was sensitive to childhood illnesses and possibly to chronic emotional disturbances. These observations indicate that leg length and trunk length may act as markers of exposures operating at different stages during childhood and may reflect social class-related differences in terms of altered skeletal size and proportions that, in turn, differently determine risks of adult non-communicable diseases.

In big metropolitan cities of India, obesity is on the rise among adolescent children, especially from the urban affluent population, while distinct undernutrition exists among adolescents from the low or poor-income class. From the above-cited studies one could expect that social class-related differentials will not only be reflected in terms of adiposity but also in terms of skeletal growth. It would therefore be worth exploring whether skeletal growth markers could mediate the relationship between

*Corresponding author: Email raoari@yahoo.com

social class and blood pressure after adjusting for adiposity. The present study examined blood pressure levels, adiposity and growth of adolescent boys from high and low social classes.

Methods

Subjects

Two schools, one convent public school catering to children from the urban affluent high socio-economic (HSE) class and the other catering to children from lower socio-economic (LSE) class, were considered for the study. These two schools represent the elite and the lower class of society, and there were enormous differences in the school tuition fees. In the LSE school, a large proportion of the parents (52·5 % of mothers and 27·4 % of fathers) were illiterate and those who were literate had education only up to 4th standard (35·3 % of mothers and 48·2 % of fathers). In contrast, none of the parents of boys in the HSE school were illiterate and in fact almost all had education at least up to graduation. With regard to occupation too, the social class differences were prominent. In the LSE school, most parents (mothers 53·9 % and fathers 59·9 %) were engaged in unskilled jobs, while the majority of parents of boys from the HSE school were either businessmen or professionals. A cross-sectional study was conducted by the complete enumeration method. Thus all boys from 5th to 10th standard in these schools, covering the age 9–16 years, were included in the study (*n* 1146 in HSE school, *n* 932 in LSE school). Absentees (5·7 % in HSE school, 6·8 % in LSE school) on the actual survey days were the only exclusions. Approval for the study was granted by the Institutional Research Advisory Committee.

Measurements

Anthropometric measurements were recorded in duplicate by trained investigators using standard procedures; nevertheless, an inter-observer variability study was done before starting the study. Weight was recorded (to the nearest 20 g) using an electronic digital balance (model SYSP Class III; Suysan, Pune, India), while standing height and sitting height were measured by stadiometer (to the nearest 0·1 cm). For measuring sitting height, the subject was asked to sit erect on a stadiometer placed on a sturdy table. The height of the table and the footrest was adjusted in order to ensure that a right angle was formed at the knee joint. The subject was asked to keep his hands comfortably placed on his lap during the measurement. Leg length was estimated by subtracting sitting height from the total height. Body fat was measured using a body fat analyser (model HBF 300; Omron, Japan), which works on the principle of bioelectrical impedance analysis. Age assessment was done using birth date records from the school.

Systolic blood pressure (SBP) and diastolic blood pressure (DBP) were measured with a mercury sphygmomanometer by a paediatrician accompanying the team. The readings were taken on the left arm using an appropriate child-sized cuff, with the subject in sitting position and having rested for at least 10 min. Since the measurements on the students were taken during school times, we were constrained to take a single measurement of blood pressure.

Definitions

Overweight

Overweight was defined using BMI and percentage body fat. Age- and sex-specific cut-offs for BMI developed by Cole *et al.*[6] were used to define overweight boys. These cut-offs are linked with the adult cut-off and extrapolated to childhood as proposed at the International Obesity Taskforce meeting in 1997[7]. In the case of percentage body fat, the conventional cut-off ($\geq$25 % for boys) defined by Williams *et al.*[8] was used.

Stunting

Z-scores of height-for-age were computed using the National Center for Health Statistics median as standard and boys with *Z*-score <-2 were considered stunted[9].

High blood pressure

We defined high SBP (HSBP) and high DBP (HDBP) independently when measured SBP or DBP of a boy was above the 95th percentile value for his age, sex and height percentile, as recommended by the National High Blood Pressure Education Program[10]. This corrects for the effect of height on blood pressure and allows the severity of blood pressure elevation to be compared between groups of boys of different heights.

Statistical methods

Age adjustment was required in both social classes, in view of the significant ($P < 0{\cdot}000$) correlation of age with BMI ($r = 0{\cdot}22$ and $0{\cdot}33$ for LSE and HSE, respectively). For a given age group, mean values of various anthropometric measurements for the two social classes and mean values of blood pressure measurements among overweight and non-overweight groups of boys were tested using Student's *t* test. The proportions of boys with HSBP in overweight and non-overweight groups were tested using the *Z*-test. Linear trends in various anthropometric measurements by age were tested using ANOVA, while proportions of overweight boys by BMI and percentage body fat tertiles were tested using the *Z*-test for a linear trend in proportion[11]. Logistic regression modelling was performed for computing the odds ratios for risk of HSBP and HDBP with the higher tertile of leg length or the higher tertile of the ratio of leg length to height as the reference category. The odds ratios were adjusted for BMI using BMI as a covariate in the regression equation. All analyses were carried out using the SPSS/PC+ for Windows statistical software package version 11·0 (SPSS Inc., Chicago, IL, USA).

Results

HSE boys were heavier by 10–12 kg, had BMI higher by about 4–5 kg/m^2 and had mean percentage body fat higher by 5–6% in every yearly age group ($P<0.01$ for all) compared with LSE boys, showing higher adiposity. Mean values of most measurements showed an increasing trend ($P<0.01$ for all) with age, except for percentage body fat, in both social classes. LSE boys were shorter than their HSE counterparts by about 12 cm up to the age of 13 years, thereafter the difference in mean heights decreased to 4 cm by the age of 15 years. The reduction in height difference was mainly due to catch-up of leg length among boys from LSE class, which was not seen in the case of sitting height (Fig. 1).

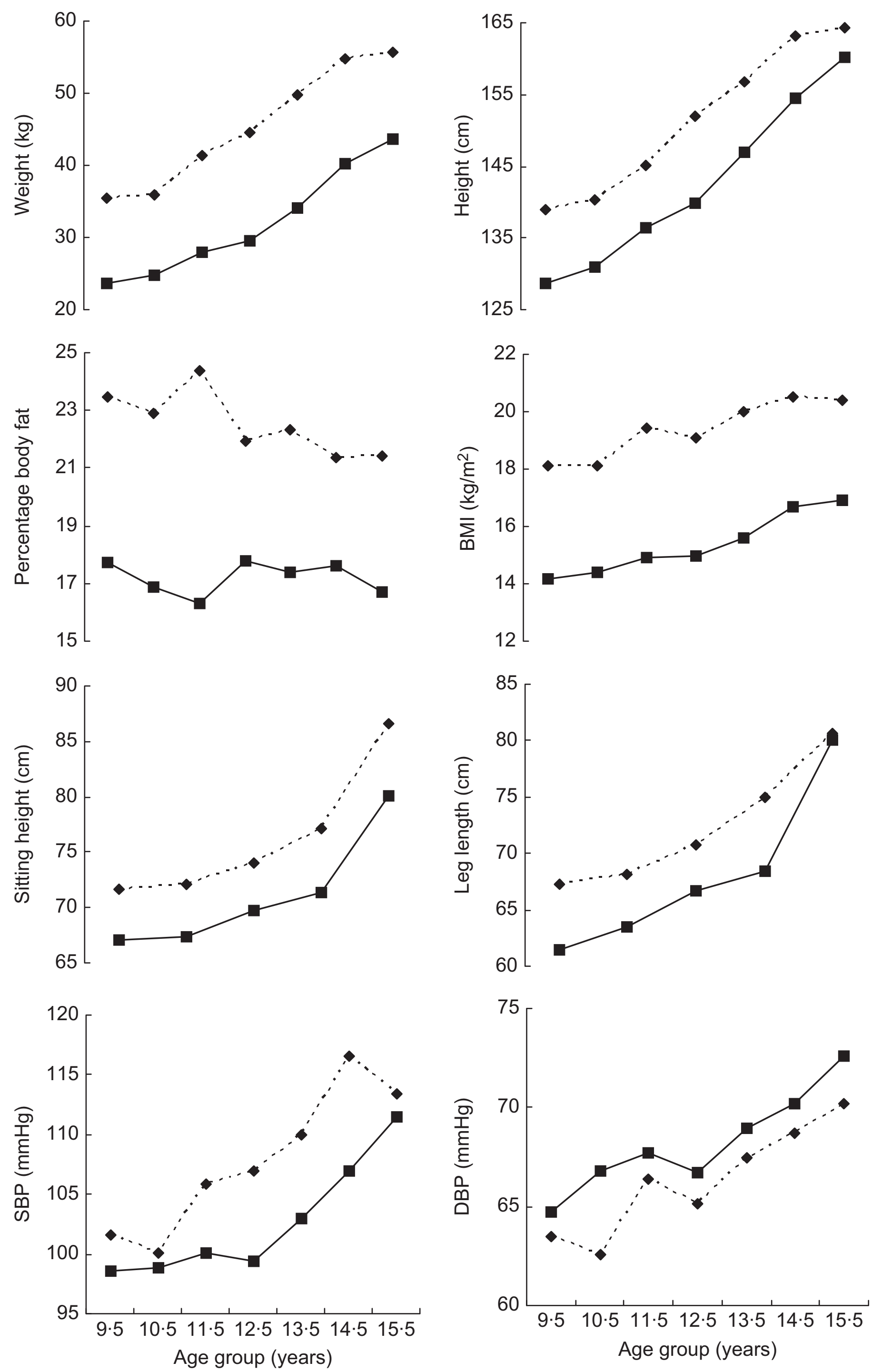

Fig. 1 Mean values of anthropometric and blood pressure (SBP, systolic blood pressure; DBP, diastolic blood pressure) indicators by age among adolescent boys from lower socio-economic class (—■—) and high socio-economic class (- -◆- -), Pune, India

Table 1 Prevalences of overweight, stunting, high systolic blood pressure (HSBP) and high diastolic blood pressure (HDBP)† by age among adolescent boys from lower socio-economic class (LSE) and high socio-economic class (HSE), Pune, India

Class/age (years)	*n*	Overweight (%) BMI	Overweight (%) % Body fat	Stunting (%)	HSBP (%)	HDBP (%)
LSE						
<12	334	1·5	8·7	24·3	3·6	9·6
12–14	291	0·0	6·6	33·3	2·1	10·0
>14	307	1·6	3·6	25·7	2·3	9·8
Total	932	1·1	6·2	27·6	2·7	9·8
HSE						
<12	537	27·9	44·4	2·2	7·4	9·3
12–14	409	22·7	30·3	2·2	11·0	4·9
>14	200	20·2	26·5	6·0	17·5	5·0
Total	1146	24·7	36·2	2·9	10·5	7·0

†Overweight defined according to BMI (age- and sex-specific cut-offs[6]) and percentage body fat (≥25 % for boys[8]); stunting as height-for-age *Z*-score <−2[9]; HSBP or HDBP as SBP or DBP >95th percentile value for age, sex and height[10].

Mean blood pressure levels increased ($P<0·01$) with age. Mean SBP was higher ($P<0·01$) for HSE boys, while mean DBP values were higher, although not statistically significantly so, for LSE boys (Fig. 1).

The prevalence of overweight was significantly higher ($P<0·01$) in HSE class, while that of stunting was significantly higher ($P<0·01$) in LSE class. When percentage body fat was used as indicator, the overweight prevalence was higher than that based on BMI in both social classes, suggesting relatively high body fat content even at low levels of body weight. Compared with their respective counterparts, the prevalence of HSBP was considerably higher ($P=0·00$) and was larger than the prevalence of HDBP in boys from HSE class, while the reverse was true for boys from LSE class ($P=0·00$; Table 1).

We examined the correlation of BMI and percentage body fat with blood pressure levels. The correlations of BMI with both SBP and DBP were significant but were higher in magnitude in the case of SBP ($r=0·476$, $P<0·001$ in LSE and $r=0·577$, $P<0·001$ in HSE) than with DBP ($r=0·316$, $P<0·001$ in LSE and $r=0·378$, $P<0·001$ in HSE) in both social classes. However, correlations of body fat with blood pressure levels were considerably low, especially in LSE class.

Table 2 gives the tertile values for BMI and body fat according to age, which were used to place each individual in his respective tertile position. In HSE class, the prevalence of HSBP was higher than that of HDBP in each of the tertiles ($P<0·05$) of BMI as well as percentage body fat. However, in LSE class, the prevalence of HDBP was significantly ($P=0·00$) higher than that of HSBP in each of these tertiles (Fig. 2). Moreover, in HSE class, the prevalence of HSBP was highest only in the third tertile, while the prevalence of HDBP in LSE boys was considerably higher even in the lowest tertile (by 7–8 % for the lower tertile of any measure). In fact, HDBP prevalence in LSE boys was notably higher ($P<0·05$) than that observed in HSE boys in both the lower tertiles but was not statistically significant in the highest tertile of these measurements. In addition, high blood pressure was associated with higher BMI as well as higher percentage body fat in HSE class but this was true only for BMI in LSE class.

Table 2 Tertile values for BMI (kg/m^2) and percentage body fat according to age among adolescent boys from lower socio-economic class (LSE) and high socio-economic class (HSE), Pune, India

Age (years)		LSE Lower	LSE Higher	HSE Lower	HSE Higher
9–10	BMI	13·46	14·84	16·04	19·43
	Body fat	14·40	20·83	20·40	26·60
10–11	BMI	13·74	14·56	16·09	18·84
	Body fat	14·73	18·63	20·20	26·03
11–12	BMI	14·06	15·10	17·47	20·44
	Body fat	13·56	18·26	21·96	27·40
12–13	BMI	14·37	15·22	17·01	19·77
	Body fat	14·23	18·43	19·23	24·13
13–14	BMI	14·87	16·41	17·85	20·99
	Body fat	14·70	18·60	19·60	24·56
14–15	BMI	15·72	16·97	18·50	21·77
	Body fat	15·06	18·56	19·10	23·46
15–16	BMI	15·85	17·44	18·65	21·57
	Body fat	14·43	17·46	19·50	24·16

In view of this weaker association of body fat with blood pressure levels in LSE class, we examined whether risk could be better explained by indicators of skeletal growth retardation which was more predominant in LSE class. Considering the higher tertile as reference category, odds ratios for the risk of high blood pressure were computed for boys in lower and middle tertiles of leg length as well as of its ratio to total height (Table 3). In the case of leg length, in both classes, boys in the lower tertile showed OR values which were less than one and a non-significant risk of HSBP, while the OR values for risk of HDBP were greater than one and also not significant. However, for the ratio of leg length to total height, OR values for both HSBP and HDBP increased gradually with the highest values for boys in the lower tertile. The odds for HDBP in LSE boys (OR = 1·99, 95 % CI 1·14, 3·47) and for HSBP in HSE boys (OR = 1·69, 95 % CI 1·02, 2·77) were statistically significant ($P<0·05$), thus indicating that rather than leg length, its ratio to total height was better in revealing the differential risks in the two social classes.

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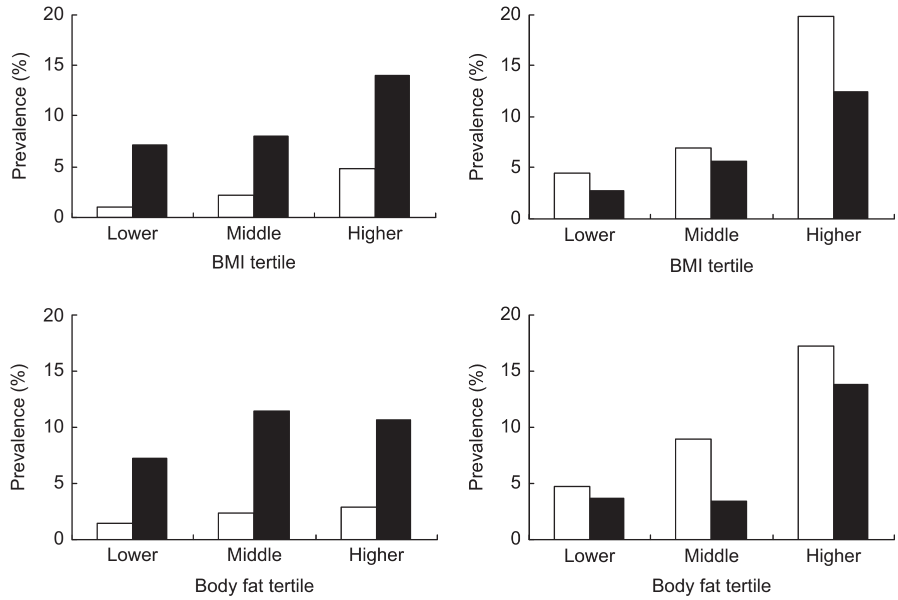

Fig. 2 Prevalence of high systolic blood pressure (□) and high diastolic blood pressure (■) by tertile of adiposity among adolescent boys from lower socio-economic class (left panels) and high socio-economic class (right panels), Pune, India

Table 3 Odds ratios and 95 % confidence intervals (BMI-adjusted) for high systolic blood pressure (HSBP) and high diastolic blood pressure (HDBP) by tertile of leg length and its ratio to total height among adolescent boys from lower socio-economic class (LSE) and high socio-economic class (HSE), Pune, India

		LSE				HSE			
		HSBP		HDBP		HSBP		HDBP	
Indicator	Tertile	OR	95 % CI	OR	95 % CI	OR	95 % CI	OR	95 % CI
Leg length	Lower	0·50	0·15, 1·64	1·573	0·92, 2·68	0·72	0·43, 1·16	1·08	0·61, 1·89
	Middle	1·37	0·56, 3·30	1·150	0·65, 2·00	0·88	0·55, 1·37	1·00	0·57, 1·74
	Higher	1·00	ref	1·00	ref	1·00	ref	1·00	ref
Leg length to height	Lower	1·25	0·47, 3·33	1·99*	1·14, 3·47	1·69*	1·02, 2·77	1·30	0·74, 2·28
	Middle	0·95	0·32, 2·75	1·27	0·70, 2·31	1·11	0·65, 1·89	0·76	0·40, 1·42
	Higher	1·00	ref	1·00	ref	1·00	ref	1·00	ref

ref, reference category.
*$P < 0{\cdot}05$.

Discussion

The notion that exposures operating during childhood that influence growth are important in the aetiology of CHD is gaining interest. Owing to scarcity of data on childhood measurements, leg length is emerging as an adult biomarker of childhood exposures[12–14]. We examined the social class-related gradient in skeletal growth, adiposity and blood pressure levels among adolescent boys from low and high socio-economic class in India. Prominent social class differences were observed in skeletal growth, adiposity and the prevalence of high blood pressure. Furthermore, the compromised growth of stature, especially leg length, was associated with higher risk of HSBP in HSE class and HDBP in LSE class.

It may be worthwhile to consider some points before discussing the major findings of our study. That only a single observation was available on blood pressure is a limitation of the study and perhaps may be the reason for the high prevalences of high systolic and diastolic blood pressures observed in this population. However, it cannot be overlooked that the data were able to reveal differing trends in blood pressure of boys from the two social classes. Second, measurement of percentage body fat by bioelectrical impedance using the Omron analyser has some concern but is the best possible option available, especially in field studies. Finally, the cut-off points used for defining HSBP and HDBP were based on international standards as no such standards are available for Indian children or Asian children in general.

Social class-related differences were prominent for various body measurements and revealed large differences which are almost similar to those observed between children from developed and developing countries[15]. Adiposity (weight, BMI, body fat) was characteristically high in HSE class while stunting was high in LSE class.

By the age of 15 years, the differences in leg length became non-significant and one explanation is that it is the component of stature known to be responsible for the greater part of prepubertal height increases[12,15,16]. Our observation confirms the earlier report by Tanner *et al.*[17] that the catch-up growth during adolescence probably occurs more in leg length than trunk length.

The correlation of BMI with body fat was higher in HSE class ($r = 0{\cdot}807$, $P < 0{\cdot}001$) compared with that seen in LSE class ($r = 0{\cdot}319$) and appeared to be a better indicator of adiposity than body fat in HSE class. Consequently, associations of blood pressure levels with body fat were much lower in LSE class. In contrast, the association of height-for-age *Z*-score with HSBP was significantly higher in both classes ($r = 0{\cdot}221$, $P < 0{\cdot}01$ in LSE and $r = 0{\cdot}308$, $P < 0{\cdot}01$ in HSE), indicating that skeletal growth markers may be better in reflecting social class-related differences in adiposity and related health risks.

Social class-related differences in prevalence of high blood pressure among adolescents have rarely been reported. In our study, the prevalence of HSBP was associated with adiposity (BMI and body fat) while the prevalence of HDBP was associated with stunting. Therefore our findings suggest that high systolic blood pressure was the health consequence of adiposity in HSE class, while high diastolic blood pressure appeared as the health consequence of growth retardation in LSE class.

A number of studies have shown an association of height, especially leg length, with SBP and CVD risks[12,13], diabetes and insulin resistance[18] and dementia[19] in different populations. Our findings show that boys with lower values of leg length to height ratio had significantly higher OR for HSBP in HSE class and for HDBP in LSE class. Thus despite the distinct social class differences, leg length to height ratio was a better indicator in revealing the respective health risks. Since leg length is emerging as an adult biomarker of diversity of childhood exposures, our observation suggests a possible role for factors other than adiposity in the development of hypertension in the case of children from LSE class.

In 1951, Leitch reported that if the rate of growth is slowed, the adult is not only small but also underdeveloped with normal or nearly normal size head, moderately retarded trunk and relatively short legs[20]. It has been reported that coronary vessel diameter increases with height and this in turn may be associated with decreased risk of luminal occlusion[14]. Our findings therefore suggest that smaller leg length to height ratio indicates the influence of factors over and above the childhood exposures, perhaps pointing towards the developmental origins of hypertension. In view of these results, urgent public health actions are required to prevent a significant rise in CVD risks in the near future. Finally, because stunting is a major problem in India and Asia, and several countries are witnessing nutritional transition, it is necessary to examine whether somatic proportions have the same capability in distinguishing CVD risk across different populations.

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