RESEARCH PAPER

Body Fat Indices for Identifying Risk of Hypertension in Indian Children

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Background: High adiposity is major risk factor for hypertension. Various anthropometric indices are used to assess excess fatness.

Objectives: (1) To examine relationship of body mass index (BMI), waist circumference (WC), waist to height ratio (WHtR), triceps skin fold thickness (TSFT) and wrist measurements with blood pressure in children and adolescents 2) to suggest age- and gender-specific cutoffs for these indices in Indian children.

Methods: Cross-sectional school-based study on a random sample of 6380 children (6-18 yr old, 3501 boys) from five major cities in India. Height, weight, waist and wrist circumference, TSFT, and blood pressure were recorded. Children with systolic blood pressure (BP) and/or Diastolic BP >95th percentile were classified as hypertensive.

Results: Prevalence of overweight and obesity was 23.5% and 9.7%, respectively. Hypertension was observed in 5.6%. Multiple logistic regression (adjustments: age, gender) indicated double risk of hypertension for overweight and 7 times higher odds for obese than normal-weight children. Children with TSFT >95th centile for US children showed three times risk and with TSFT from 85th to 95th double risk of hypertension. Higher WC and WHtR exhibited 1.5 times risk and larger Wrist 1.3 times higher risk of hypertension (P<0.001). Receiver operating curve (ROC) analysis provided age-gender specific cut offs for the five indices to detect the risk of high BP. Area under ROC curves (AUC) for five indices were similar and greater in older age groups indicating equal sensitivity and specificity.

Conclusion: Using age- and gender-specific cutoffs for BMI, TSFT, WC or WHtR may offer putative markers for early detection of hypertension.

Keywords: *Anthropometry, Blood Pressure, Body mass index, Waist circumference.*

Children are becoming overweight and obese at progressively younger ages throughout the world, both in high-income as well as middle- and low-income populations [1]. Obesity is identified as the most important risk factor affecting blood pressure (BP) distribution in children [2,3]. Increasing evidence suggests that adult BP is correlated with childhood BP and body size [4]. Normal range of BP in childhood varies with age and gender [5]. Identifying risk of hypertension becomes difficult for want of easy access to age- and gender-specific values. Considering the strong correlations of anthropometric parameters such as body mass index (BMI) and waist circumference (WC) with BP [6], an indirect assessment of high BP using these indices may be an efficient strategy in the community setup.

Excess body fat or adiposity is an important cardio-metabolic risk factor than excess body weight *per se*. Since BMI does not differentiate between fat and lean, other surrogate measures of body fat distribution such as WC, triceps skin fold thickness (TSFT), waist to height ratio (WHtR) are presently being evaluated for their association with metabolic risk [7-10]. While WC is a crude measure of intra abdominal fat, TSFT is predictive of body fat and metabolic risk in children and adolescents [11-13]. Measurement of Wrist circumference (WrC) is also an easy-to-detect clinical marker to identify at risk children [14]. Although there are ethnic-specific definitions for general and central obesity [15,16], few studies have compared ability of various adiposity indices and provided age-gender specific cut offs for screening children and adolescents for the risk of hypertension.

Therefore, the objectives of the present study were (*i*) to investigate relationships of BMI, WC, WHtR, TSFT and Wrist circumference with BP; and (*ii*) to provide optimal cut off points for these indices for detecting hypertension.

METHODS

The study was performed in schools from five major Indian cities (Chennai, Delhi, Kolkata, Pune and Raipur), between July 2011 and January 2012). Schools were randomly selected from the list of private schools catering to well-off families in each city. The mean yearly fees of the schools were INR 26,000 (15,000 to 54000). All apparently healthy children from 6 to 18 years of age from the selected school were included after informed

written consent from parents and assent from children. The exclusion criterion was children with pre-existing serious illnesses. The study was approved by the ethics committee of the Hirabai Cowasji Jehangir Medical Research Institute.

A single team led the data collection at each site and equipments were calibrated daily. Mean inter-observer and intra-observer coefficients of variation were both < 0.01(1%) for height (Ht), Weight (Wt), Waist Circumference (WC), Tricep Skin fold Thickness (TSFT), Wrist circumference and Blood Pressure measurements, and differences between observers were not statistically significant.

Anthropometric measurements: Standing height was measured using a portable stadiometer (Leicester Height Meter, Child Growth Foundation, UK). Weight was measured using electronic scales (Salter, India) measuring up to 100 g. BMI categories were defined as (*a*) Normal weight, (*b*) Overweight and (*c*) Obese using contemporary Indian data [17] and height for age, weight for age and BMI for age z-scores were computed using Indian reference data [18]. WC was measured in standing position, by a stretch resistant tape which was applied horizontally just above the uppermost lateral border of the right ileum using NHANES protocol [19]. WC above 90th centile of available reference population [20,21] was considered as Adipose. Waist to height ratio (WHtR) was computed and Optimal cut-off value of 0.44 WHtR for children and adolescents was used to classify children as normal or adipose [22]. TSFT was recorded using Harpenden calliper, on the non-dominant upper arm as per standard protocol [23]. Children were classified as normal (< 85th centile), moderate (85th -95th) and excess fat (>95th centile) with respect to references centiles. In absence of Indian reference data for TSFT, Western cut-Offs were used [24]. Similarly, Wrist circumference was measured using stretch resistant tape using NHANES protocol [19]. The most prominent aspect of the radial styloid process was located with the middle or index finger of the left hand. Firm pressure was applied and the circumference was recorded to the nearest 0.1 cm [19]. Average of two readings for all parameters was used for analysis.

Clinical assessments were carried out by pediatricians. BP was recorded with children sitting and the cubital fossa supported at heart level, after at least 5 minutes rest. BP was measured using a mercury sphygmomanometer, with appropriate cuff. In case of a high reading, BP was measured again after an interval of 10 minutes and also confirmed by another investigator. Systolic BP (SBP) and/or Diastolic BP (DBP) >90th percentile and <95th percentile was considered as pre-hypertension; and SBP and/or DBP >95th percentile were classi-fied as hypertensive [5]. To account for changes in anthropometric measures and later growth spurt in boys following age groups were defined: boys 6-12, 13-15, 16-18yrs; girls 6-9, 10 -14, 15-18 yrs [25].

Children with persistently high BP underwent a further diagnostic workup for causes of hypertension including familial, renal, obesity, etc.; children with pre hypertension were managed on diet and lifestyle changes, while those with blood pressure above the 95th percentile were either advised the same and followed up or were initiated on therapy with anti-hypertensive treatment [5].

Statistical methods: SPSS version 20.0 (Chicago, 2011) was used for analysis. All results are expressed as mean (SD). Correlations were estimated (unadjusted and after age adjustment) separately for both genders to examine association of anthropometric measurements with BP. Level of significance was set at $P<0.05$. Two separate multiple logistic regression models adjusted for age and gender were used to examine relationship of hypertension with BMI categories, TSFT classes and Wrist with WC categories in the first model, and with WHtR categories in the second model to avoid multi-collinearity. Receiver-operating characteristic (ROC) curve analysis was performed to evaluate the accuracy of each index (i.e., BMI, WC, WHtR, TSFT, WrC) to discriminate between presence or absence of hypertension. The area under each ROC curve (AUC) and 95% confidence intervals (CI) were estimated to compare the relative ability of various anthropometric indices to identify risk of high BP. Optimal cut-off points for each anthropometric indicator were determined [26,27]. The differences between area under ROC curves for BMI, WC, WHtR, TSFT and WrC to determine the best predictor for hypertension was tested [28].

RESULTS

Age-and gender-wise anthropometric characteristics of children aged 6-18 years (total 6380, 3501 boys) are described in ***Table* I**. In each age group, boys had higher mean values of Ht, Wt, BMI, WC, WrC and BP than girls ($P<0.05$) except for TSFT.

A significant positive association (r=0.85) was observed between BMI and WC in boys and girls within each age group ($P<0.001$). Correlations of BMI with TSFT and WHtR were 0.78 to 0.80, respectively across age groups in both genders ($P<0.001$). BMI showed higher correlation with Wrist (r= 0.70) in younger age group which reduced to 0.6 and then to 0.45 in older groups ($P<0.001$). WC was positively correlated with

TABLE I CHARACTERISTIC OF STUDY POPULATION ACCORDING TO AGE GROUPS

Boys	*(6-12 yrs) (1731)*	*(13-15 yrs) (1417)*	*(16-18 yrs)(375)*	*All (6-18yrs) (3501)*
Age (years)	9.1 ± 1.7	13.8 ± 1.1[a]	16.7 ± 0.6[b,c]	11.8 ± 3.1
Height (cm)	132.4 ± 11.4	159.6 ± 10.2[a]	170 ± 6.7[b,c]	147.4 ± 18.3*
Weight (kg)	29.6 ± 9.2	49.8 ± 12.9[a]	60.2 ± 12.4[b,c]	40.9 ± 16.1*
BMI (kg/m^2)	16.5 ± 3	19.3 ± 3.8[a]	20.8 ± 3.7[b,c]	18.1 ± 3.8
Height for age Z score	-0.2 ± 1.1	-0.1 ± 1	-0.7 ± 0.9	-0.2 ± 1
Weight for age Z score	-0.2 ± 1.4	0 ± 1.3	-0.5 ± 1.4	-0.2 ± 1.3
BMI for age Z scores	-0.2 ± 1.5	0 ± 1.5	-0.1 ± 1.4	-0.1 ± 1.5
Waist (cm)	65.1 ± 8.4	78 ± 9.2[a]	82 ± 8.6[b,c]	72.1 ± 11.2
Waist to height Ratio (WHtR)	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
Wrist (cm)	12.5 ± 1.2	14.3 ± 1.2[a]	14.9 ± 0.9[b,c]	13.5 ± 1.6*
Tricep Skin Fold Thickness (mm)	10.6 ± 5	11.9 ± 6.4[a]	11.0 ± 5.7	11.1 ± 5.7*
Systolic BP (mm/Hg)	98.5 ± 10.5	109.6 ± 10.5[a]	115.1 ± 9.4[b,c]	104.8 ± 12.2
Diastolic BP (mm/Hg)	66.2 ± 7.8	72.2 ± 7.8[a]	75.4 ± 6.6[b,c]	69.6 ± 8.4
Girls	*(6-9 yrs)(811)*	*(10- 14 yrs) (1199)*	*(15-18 yrs) (869)*	*All (6-18 yrs) (2879)*
Age (years)	7.9 ± 1.1	12 ± 1.2[a]	15.6 ± 1.1[b,c]	11.9 ± 3.1
Height (cm)	125.1 ± 8.3	148.1 ± 9.3[a]	156.4 ± 6.1[b,c]	144.1 ± 14.9
Weight (kg)	25.1 ± 6.7	40.9 ± 10.1[a]	50.9 ± 9.8[b,c]	39.4 ± 13.5
BMI (kg/m^2)	15.8 ± 2.9	18.4 ± 3.3[a]	20.7 ± 3.6[b,c]	18.4 ± 3.8
Height for age Z score	-0.2 ± 1.1	-0.2 ± 1.0	-1.0 ± 1.0[b]	-0.4 ± 1.1
Weight for age Z score	-0.4 ± 1.4	-0.1 ± 1.2	-0.6 ± 1.3[b]	-0.4 ± 1.3
BMI for age Z scores	-0.4 ± 1.4	-0.1 ± 1.3	0 ± 1.3	-0.2 ± 1.4
Waist (cm)	61.9 ± 7.6	73.5 ± 8.7[a]	79.6 ± 8.7[b,c]	72.1 ± 10.8
Waist to height Ratio (WHtR)	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1	0.5 ± 0.1
Wrist (cm)	11.7 ± 1	13.2 ± 1.1[a]	13.5 ± 1[b,c]	12.8 ± 1.3
Tricep Skin Fold Thickness (mm)	11 ± 4.4	14.0 ± 5.4[a]	15.9 ± 5.7[b,c]	13.7 ± 5.6*
Systolic BP (mm/Hg)	95.6 ± 9.7	105.7 ± 10.3[a]	110.7 ± 9.4[b,c]	104.4 ± 11.5
Diastolic BP (mm/Hg)	64.6 ± 7.5	70.2 ± 7.9[a]	73.5 ± 7[b,c]	69.6 ± 8.3

*!Values are expressed as mean ± SD. * significantly different than other age matched gender, p<0.05; [a]Group II significantly higher than group I , p<0.05; [b]Group III significantly higher than group I, p<0.05; [c]Group III significantly higher than group II. p<0.05.*

TSFT (r = 0.67 - 0.74, *P*<0.001) and Wrist (r= 0.41 - 0.78, *P*<0.001) in both genders across all groups (Data not shown).

Overall prevalence of hypertension was higher in boys (6.7%) than girls (4.2%) (*P<0.05*) with higher percentage in the younger age groups than older age group. Prevalence was also higher in overweight/obese than normal girls (*P<0.05*) which decreased with increasing age. In boys, prevalence of hypertension amongst overweight/obese was higher from 13-15yrs (***Fig.* 1** and **2**).

Gender wise correlations between SBP, DBP and anthropometric indices are presented in ***Table* II**. All correlations were positive and significant (*P*<0.001). In both genders, correlation coefficients for BMI and WC with SBP were around 0.5 (*P*<0.001). WHtR showed a low correlation with SBP and DBP in both genders.

Multiple logistic regression model 1 (adjustment: age, gender) indicated that odds ratios (OR) for BMI categories, waist centile classes, TSFT centile classes, and Wrist against high BP were statistically significant (*P*<0.001) (***Web Table* I**). Overweight children showed double risk of hypertension and obese children 7 times higher risk than normal weight children. TSFT >95th centile showed almost 3 times risk and between 85th-95th double risk than normal weight children. Higher WC (>90th centile) also exhibited 1.5 times risk and larger Wrist 1.26 times higher risk of hypertension. The model

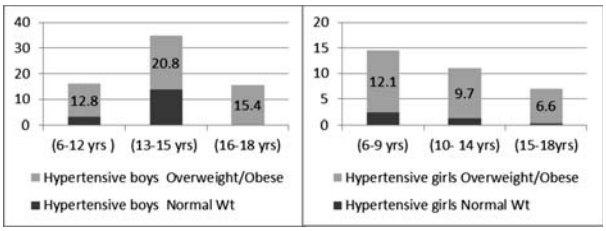

FIG. 1 *Prevalence of hypertension across BMI category in boys and girls.*

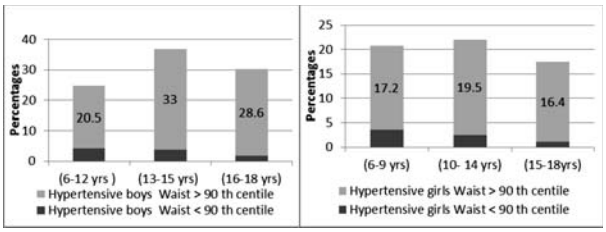

FIG. 2 *Prevalence of hypertension across the waist centile categories in boys and girls.*

TABLE II CORRELATION BETWEEN SYSTOLIC BP (DIASTOLIC BP) AND ANTHROPOMETRIC INDICES IN BOYS AND GIRLS

Anthropometric	*Boys*			*Girls*		
Index	*6-12 yr*	*13-15 yr*	*16-18 yr*	*6-9 yr*	*10-14 yr*	*15-18 yr*
BMI	0.53 (0.34)	0.57 (0.45)	0.59 (0.46)	0.45 (0.29)	0.57 (0.41)	0.47 (0.42)
Waist	0.58 (0.39)	0.52 (0.41)	0.48 (0.35)	0.46 (0.28)	0.55 (0.40)	0.40 (0.33)
WHtR	0.31 (0.21)	0.31 (0.29)	0.42 (0.29)	0.28 (0.17)	0.41 (0.29)	0.34 (0.28)
TSFT	0.47 (0.30)	0.37 (0.29)	0.52 (0.34)	0.45 (0.31)	0.48 (0.35)	0.27 (0.30)
Wrist	0.52 (0.37)	0.46 (0.35)	0.28 (0.24)	0.42 (0.31)	0.41 (0.32)	0.25 (0.24)

$P<0.001$ for all comparisons.

2 (WHtR in place of WC) showed that estimated risk of hypertension was similar as 1.5 times in children with high WHtR (>0.44) than normal WHtR (<0.44) children ($P<0.0001$). Thus all these indices showed ability to predict risk of hypertension.

Table* III** describes the age- and gender-specific optimal cut-off values and for each of the five anthropometric indices in detecting the risk of high BP. With growing age, all the body measurements showed increasing trend which is reflected in higher cut offs for BMI, WC, WHtR, TSFT and WrC in older age groups in both genders. Sensitivity and specificity of all the indices were similar ranging from 60 to 90%. The Area under curve was also significantly high, different from 0.5 for BMI, WC, WHtR, TSFT and Wrist for both genders (Web Table* II**) indicating the ability of these anthropometric indices for detecting the risk of high BP. Overall comparison of the five indices in different age-gender groups suggests that BMI, WC and TSFT are better indicators of risk of hypertension.

DISCUSSION

All five indices showed significant positive association with BP and indicated that obese children were seven times at risk of hypertension than normal-weight children. We have also proposed age-gender specific cut-off values for these five anthropometric indices. For boys, BMI, WC and TSFT showed similar predictive power while in girls all five indices performed equally well.

The prevalence of hypertension in our study was higher than that reported previously [9]. Further, the prevalence of high blood pressure was more in boys than in girls, which is also reported by other studies [9]. Similar to earlier studies we also found that pubertal subjects had higher prevalence of hypertension than pre-pubertal subjects [29]. Though studies describing prevalence of hypertension in various age groups similar to ours are scarce, studies in obese children have shown that cardiovascular risk factors worsen at onset of puberty and improve in later puberty, a result similar to that seen in the current study [30].

In the present study, we have provided cut-off values for various anthropometric indices *i.e*. BMI, waist

TABLE III CUT-OFF VALUES OF ANTHROPOMETRIC INDICES FOR PREDICTION OF HYPERTENSION IN CHILDREN

Anthropometric	*Group I*		*Group II*		*Group III*	
Index	*Boy*	*Girls*	*Boys*	*Girls*	*Boys*	*Girls*
BMI (kg/m^2)	17.5	16.1	21.8	19.2	26.1	22.7
Waist (cm)	68	62	81	77	90	87
WHR	0.50	0.51	0.53	0.51	0.53	0.55
TSFT (mm)	10.6	13.3	14.5	16.8	17.4	18.4
Wrist (cm)	12.9	12.1	14.8	13.5	15.9	13.7

Group I: 6-11 yr boys & 6-9 yr girls; Group II: 12-15 yr boys & 10-14 yr girls: Group III: 16-18 yr boys & 15-18 yr girls.

WHAT IS ALREADY KNOWN?

- Anthropometric parameters are positively correlated with blood pressure.

WHAT THIS STUDY ADDS?

- Age- and gender-wise cutoffs are provided for simple anthropometric indices such as BMI, Waist Circumference, Waist to Height ratio, Tricep Skinfold thickness and Wrist circumference for screening for risk of hypertension in Indian children.

circumference, WHtR, TSFT and for the first time for Wrist circumferences for detecting risk of hypertension in Indian children. In a study on Brazilian adolescents, cut-offs for BMI were in line with our cut-offs for girls (14-18 yrs), though they were lower for boys [31]. For Iranian adolescents, cut-offs for boys and girls were lower than those reported in our study [32].

A limitation of the study is that children were classified in age groups on consideration of conventional pubertal development years. It was not possible to assess Tanner staging for each child in the present study due to logistic reasons. Second limitation of the study was non-availability of biochemical measurements, therefore examining utility of these indices for screening other cardio-metabolic risk factors was not possible. Thirdly we did not record family history of hypertension, which may have some effect on the BP status of children. Although even after adjusting for parental influence the risk in children would be significant [33]. However, for community surveys, screening for hypertension with non-invasive body measurements would go a long way in prevention of risk of cardiovascular disease in adulthood.

To conclude, all five measures of adiposity were significantly associated with risk of hypertension in a multi-centric sample of Indian children and adolescents. Age-gender specific optimal cutoffs for BMI, TSFT, WC, wrist circumference and WHtR measurements presented in the study may be useful in screening for risk of hypertension.

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Contributors: NAK: designed the data collection instruments and coordinated and supervised data collection at the sites, carried out the analysis, drafted the initial manuscript; AVK: conceptualized and designed the study, coordinated and supervised data collection, carried out the initial analyses, reviewed and revised the manuscript. She will act as guarantor of the study; SAC: conceptualized and designed the study, carried out the analyses, reviewed and revised the manuscript; VVK: conceptualized and designed the study, critically reviewed the manuscript. The final manuscript was approved by all authors.

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