RESEARCH PAPER

Percentage Body Fat in Apparently Healthy School Children From Northern India

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Context: Increased prevalence of obesity in childhood and adolescence, defined by the use of body mass index (BMI), has drawn attention towards direct measurement of body fat

Objective: To develop age-and sex-specific reference distribution of body fat in apparently healthy North-Indian children in the age group of 7-17 years and to assess agreement between obesity (defined by BMI) and excess body fat

Design: Study subjects for this cross sectional study included1640 apparently healthy school children (825 boys; 815 girls) aged 7-17 years. Total body fat was measured by dual energy X-rays absorptiometry (DXA). The excess body fat by DXA was defined by two methods, prevalence matching and with the use of 85^{th} and 95^{th} centile cutoffs.

Results: The mean ± SD, 3rd, 10th, 25th, 50th, 75th, 90th and 97th centile values of percentage body fat (PBF) are presented. PBF was highly correlated with BMI in both boys and girls (all boys: r=0.76, *P*<0.0001; all girls r=0.81, *P*<0.0001). There was no significant difference noted in PBF between boys and girls at the age of 7-8 years. From 9 years onwards, girls had significantly higher PBF than boys. Moderate degree of agreement was observed between BMI and PBF by DXA by both methods.

Conclusions: Smoothened reference distribution of PBF for North-Indian children and adolescents in Delhi are provided. Indian children accumulate more body fat during peri-pubertal years in comparison with US children.

Keywords: *Percentage body fat, Obesity, Adolescents, Reference values, India, Assessment values.*

Childhood overweight and obesity have increased dramatically since 1990. A recently published analysis of 450 nationally representative cross-sectional surveys from 144 countries showed that 43 million children (35 million in developing countries) are estimated to be overweight and obese, while 92 million are at risk of overweight [1].

Body mass index (BMI) is widely used to assess overweight and obesity, and standard cutoff values are now widely accepted for adults as well as children [2]. A major shortcoming of BMI is that it provides excess weight relative to height, not excess body fat, so it cannot differentiate between a muscular body and fatty body. The interpretation of BMI among children and adolescents has additional problems [3]. Skinfold thickness and bioelectric impedance, give variable results and thus are a less preferred approach. Recently, dual energy *X*-rays absorptiometry (DXA) has gained wider acceptability as a research tool for evaluation of body composition as it provides precise body composition analysis with a low radiation dose [4,5], is reproducible, and able to detect small changes in body composition in both, adults and children [6]. It is increasingly being used as a criterion or reference for comparison with other body composition measurement techniques [7-10] and is highly correlated with bioelectric impedance analysis (BIA), skinfold thickness, and underwater weighing [11-14].

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It is now well established that adult Asian subjects have higher levels of body fat than European subjects with comparable BMI values which has led to a revision of WHO recommendations for appropriate BMI cut-off levels in Asian populations [15]. Similar differences in total body fat have also been seen in Asian children and adolescents residing in western countries [16,17]. One of the major limitations of these studies is very small sample size of Asian-Indian subjects. However, absence of population based reference data makes it difficult to define cutoffs for excess body fat especially in Asian-Indian children and adolescents.

There have been few earlier studies aimed at defining reference intervals of percentage body fat in Asian-Indian children and adolescents. However, these studies had limitations of either a small sample size or use of skin fold thickness for calculation of percentage body fat [18,19] and none of them used DXA. We, therefore, undertook this study to develop-age and sex-specific reference distribution of body fat in apparently healthy children in the age group of 7-17 years in Northern India and to assess agreement between obesity (defined by BMI) and excess body fat (assessed by DXA).

METHODS

This cross sectional study was part of health survey of Delhi school children. Details have been published previously [20]. Brief history and tailored clinical examination related to anthropometry was carried out in 1640 children (825 boys; 815 girls) aged 7-17 years. Subjects suffering from any systemic disease (including diabetes and hypothyroidism) or on any chronic treatment for more than one month were not recruited for DXA. All subjects were transported to the study center for body fat assessment by DXA. Body weight was measured to the nearest 0.1 kg using digital weighing machine (EQUINOX Digital weighing machine, Model EB6171) and height was measured with wall mounted stadiometer (Model WS045, Narang Medical Limited, Delhi)). BMI was calculated by weight (in Kg) divided by square of height (in meter). Overweight and obesity were defined by using cutoff provided by International Obesity Task Force (IOTF, 2). The study protocol was approved by the institutional ethics committee of Institute of Nuclear Medicine and Allied Sciences (INMAS). Administrative approval was taken from school authorities, written informed consent from parents / guardians, while verbal assent was taken from the children who participated in the study. Since the number of subjects in 5-year and 18-year age group was small (12 and 16, respectively), they were not included in the final analysis.

Dual energy X-rays absorptiometry: Whole body DXA scans were performed using GE Lunar Prodigy scanner (software version 2.20; General Electric Medical Systems, Madison, WI, USA). Measurements were taken with the subject supine on the scanning table, beginning at the top of the head and moving in a rectilinear pattern down the body to the feet. The coefficient of variation of the scanner (on the basis of two consecutive scans of 15 adult subjects) was 0.44% for total fat mass. Similarly, whole body phantom was also scanned daily before subject evaluation and remained stable during study period. However, in view of additional radiation exposure, the reproducibility of these scans was not assessed among children.

There are no generally acceptable percentage cutoffs for body fat to define overweight and obesity in children. Even among adults, World Health Organization concluded that "there is no agreement about cutoff points for the percentage of body fat to constitute obesity" [14, 21]. In absence of any universal acceptance, we adopted two approaches for defining excess body fat. In the first approach ('Prevalence matching' approach or Method A, 22), we formed three categories of body fatness (normal, moderate and elevated body fat) which correspond to the three BMI categories (normal, overweight and obese as defined by IOTF cutoffs). Within each age and sex group, percentage body fat cutoffs were chosen in a way that the number of children with elevated, moderate and normal body fat would equal the number of children who had BMI in the obese, overweight and normal BMI categories. If there is perfect correlation between BMI and percentage body fat, it would result in perfect matching of three body fat categories with the three BMI categories.

The second approach (Method B), was based on use of 85th and 95th centile cut-offs for defining excess body fat as suggested [14]. We used these two cutoffs from our data set to define excess body fat. Subjects with percentage body fat <85th centile were considered as having normal body fat, those with percentage body fat between 85-95th centile as having moderate body fat and individuals with body fat >95th centile were considered as having elevated body fat.

We then looked for agreement between body fat categories (normal, moderate and elevated body fat, generated by both methods) and BMI categories (normal BMI, overweight BMI and obese BMI). We also compared percentage body fat data from our study with available similar (age and sex matched) two data sets from US population.

Statistical analysis: Analysis was performed using STATA 9.0 (College Station Road, TX, USA). Descriptive statistics were calculated as mean and standard deviations. An age specific distribution of percentage body fat was calculated separately for boys and girls. A p value of <0.05 was considered as statistically significant. Student t test for independent samples was used to compare difference in means between boys and girls. Age related reference centile curves were generated using LMS Program version 1.28 [23]. Fleiss' kappa was used for assessing the reliability of agreement.

RESULTS

Out of 1640 children (825 boys), 299 children were found to have BMI either in overweight (226, 13.8%; Boys – 15.8%; Girls – 11.8%) or obese category (73, 4.5%; Boys – 5.8%, Girls – 3.1%, based on IOTF cutoffs, ***Table* I**). The mean ± SD, 3rd, 10th, 25th, 50th, 75th, 85th and 95th centile values of percentage body fat for boys and girls are provided in ***Table* II**. Reference centile curves for boys and girls are shown in ***Figs*. 1 *and* 2,** respectively.

Percentage body fat was highly correlated with BMI in both, boys and girls (all boys $r = 0.76$, $P < 0.0001$; all girls $r = 0.81$ $P < 0.0001$). In boys, the correlation was poor in overweight ($r = 0.20$, $P < 0.01$) and obese ($r = 0.28$, $P < 0.04$) while girls showed good correlation in normal ($r = 0.78$, $P < 0.0001$) and overweight ($r = 0.53$, $P < 0.0001$) but no significant correlation in obese ($r = 0.18$, P 0.37) subjects.

The mean percentage body fat in boys was 23.5%, varying between 19.3% to 27.7 %. There was a tendency to increase in percentage body fat from 7 years to reach maximum percentage body fat by the age of 11 years of age. Thereafter, there was a trend to decrease in body fat, followed by a plateau commencing at the age of 14 years.

The mean percentage body fat in girls was 33.6%, varying between 22.4% to 37.6%. In contrast to the slopes of curves in boys, girls showed progressive increase in percentage body fat from 7th year onwards to reach peak at 17th year, a rise of 70% from the age of 7 years.

There was no significant difference noted in percentage body fat between boys and girls at the age of 7-8 years (P 0.20 and 0.49 respectively). From 9 years onwards, there was a difference in percentage body fat between boys and girls, which become heightened after the age of 12 years ($P < 0.0001$ for 12 year onwards). **Figure 3** shows changes in percentage body fat in both sexes with progression of age.

Agreement between percentage body fat and BMI

There was similar agreement between BMI categories and percentage body fat categories (moderate agreement) as assessed by both methods, though kappa was better with method A (***Web Table* I and II**). Using method A, 6.3% boys with normal BMI had moderate percentage body fat in all except one, who fell in excess percentage body fat category. Boys who were overweight (by BMI), showed more variation with 41% of these subjects having normal or excess body fat while 32% subjects in the obese group (by BMI) had either normal (13%) or moderate body fat (87%). Similar results were also observed using method B.

Similarly, using method A, 5.8% girls had moderate or excess body fat despite having BMI within normal range. Approximately 49% of girls with BMI in overweight category had either normal (91%) or excess body fat (9%) while 19.2% of obese girls (by BMI) had moderate body fat. Similar results were also observed using method B.

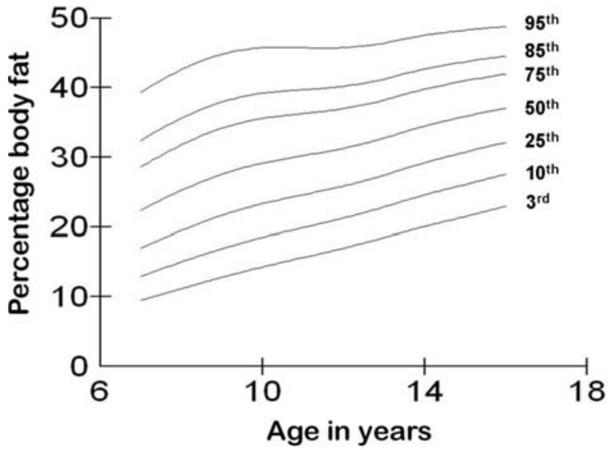

FIG. 1 *3rd, 10th, 25th, 50th, 75th, 85th, and 95th centile curves for percentage body fat for boys.*

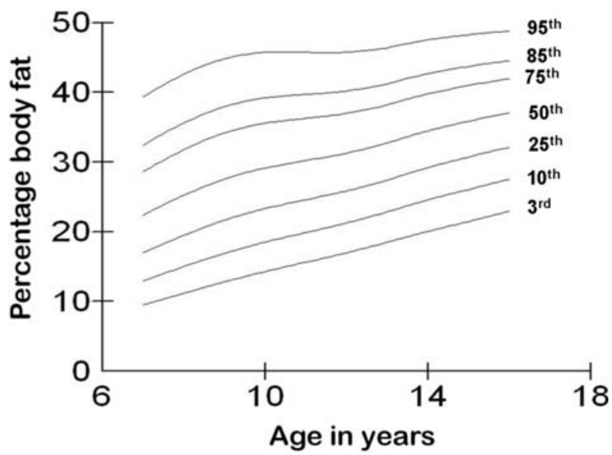

FIG. 2 *3rd, 10th, 25th, 50th, 75th, 85th, and 95th centile curves for percentage body fat for girls.*

TABLE I DISTRIBUTION OF STUDY POPULATION ACCORDING TO BMI* (IOTF# CRITERIA)

	Normal BMI	*Overweight*	*Obese*	*Total*
Boys	647 (78.4%)	130 (15.8%)	48 (5.8%)	825
Girls	694 (85.2%)	96 (11.8%)	25 (3.1%)	815
Total	1341 (81.8%)	226 (13.8%)	73 (4.5%)	1640

**BMI = Body mass index; # IOTF = International Obesity Task Force.*

TABLE II 3RD, 10TH, 25TH, 50TH, 75TH, 85TH AND 95TH CENTILE VALUES OF PERCENTAGE BODY FAT FOR BOYS AND GIRLS

Age	*n*	*Mean±SD*	*3rd*	*10thththth*	*25th*	*50th*	*75th*	*85th*	*95th*
Boys									
7	45	19.3±9.2	8.9	11.2	14.1	18.4	24.1	28.0	35.9
8	18	22.68±9.8	9.3	12.1	15.6	20.7	27.3	31.7	40.5
9	31	22.29±9.8	9.5	12.6	16.7	22.5	29.9	34.6	44.0
10	55	25.5±10.4	9.4	13.0	17.5	23.9	31.9	37.0	46.8
11	98	27.7±10.6	9.0	12.8	17.6	24.4	32.7	38.0	48.0
12	116	25.7±11.4	8.2	12.0	16.7	23.4	31.7	36.8	46.7
13	103	22.4±10.9	7.3	10.8	15.4	21.7	29.6	34.6	44.1
14	140	21.7±10.1	6.7	10.1	14.4	20.5	28.2	33.1	42.5
15	79	22.0±12.0	6.5	9.8	14.1	20.3	28.2	33.1	42.8
16	95	23.3±10.7	6.5	9.8	14.2	20.6	28.7	33.9	44.1
17	45	22.49±11.0	6.5	9.8	14.3	20.8	29.3	34.6	45.2
Girls									
7	24	22.42±8.9	9.5	12.9	17.0	22.4	28.7	32.4	39.3
8	10	25.33±10.0	11.2	15.0	19.5	25.2	31.8	35.6	42.6
9	30	29.2±9.1	12.8	16.9	21.7	27.6	34.2	38.0	44.8
10	32	30.8±10.8	14.3	18.5	23.3	29.2	35.6	39.3	45.8
11	71	30.55±8.5	15.6	19.9	24.6	30.3	36.3	39.8	45.8
12	90	31.32±8.2	17.0	21.3	25.9	31.3	37.0	40.2	45.8
13	128	32.61±7.2	18.5	22.8	27.4	32.7	38.2	41.2	46.4
14	107	35.43±8.1	20.1	24.6	29.2	34.5	39.8	42.7	47.6
15	149	35.2±8.0	21.5	26.1	30.7	35.9	41.0	43.7	48.3
16	121	37.66±6.6	23.0	27.6	32.1	37.1	42.0	44.5	48.8
17	53	37.15±7.5	24.3	28.8	33.3	38.0	42.6	45.0	49.0

Comparison of percentage body fat with NHANES data (Web Table III)

We compared percentage body fat of selected age categories from our study with age and sex match data of percentage body fat from US National Health and Nutrition Examination Survey (NHANES, 24). In the lower age group (8 years), both boys and girls from NHANES data have higher body fat than Indian children although the difference lessened as percentile increased and became almost equal at 95th centile. At the age of 10 years, Indian boys and girls had lower body fat than subjects in NHANES but this difference decreased as the centiles increased, becoming almost equal at 85th centile. However, at 95th centile, Indian boys and girls had higher body fat that their counter parts. At 13 years of age, Indian boys had lower body fat at lower centiles (10th and 25th) but equal or higher body fat at higher centiles. In contrast, Indian girls at 13 years had equal body fat at 10th centile but had higher body fat at all other centiles. In the age group of 17 years, boys had lesser body fat at lower centiles which became equal at 50th centile and later, achieved higher body fat at higher

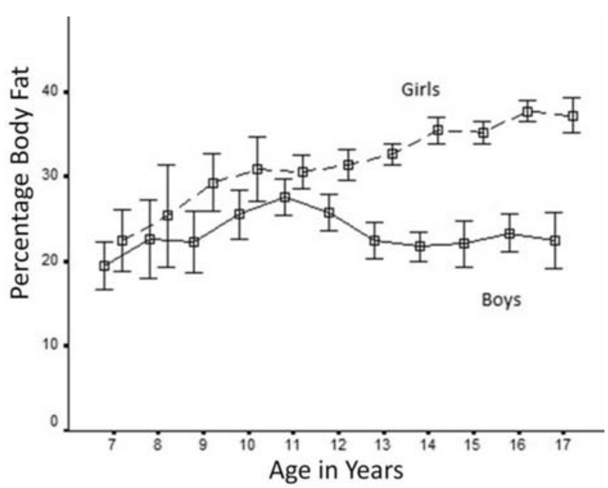

FIG. 3 *Progression of percentage body fat with age in boys and girls.*

centiles whereas girls at 17 years of age had higher body fat at all centiles when compared with NHANES data set.

Comparison of percentage body fat with New York pediatric Rosetta study

We also compared our 85th and 95th centiles of percentage body fat with age and sex matched data with New York pediatric Rossetta study [25]. Comparison of 95th centile of percentage body fat showed that boys had almost similar percentage body fat at 7 yrs of age but after that, Indian boys accumulated more fat than US boys and had higher percentage body fat in all other age groups. In contrast, Indian girls had higher percentage body fat in all age groups except 12-13 years. Similar pattern was also seen for 85th centile in all boys and girls except Indian boys at 8-9 yrs of age and Indian girls at 12-13 yrs, who had lower percentage body fat than their counterparts.

DISCUSSION

In the present study, we analyzed percentage body fat in 1640 North-Indian school children aged 7-17 years from Delhi and found high levels of percentage body fat in apparently healthy children and adolescents. The very purpose of present study was to assess the agreement between BMI and PBF and establish reference intervals for PBF for North-Indian children.

The increased prevalence of childhood obesity, dysmetabolic state and type 2 diabetes and their long-term cardiovascular risk makes measurement of body fat relevant to pediatric clinical practice and demands establishment of simple and reliable clinical methods for its assessment [26]. BMI is widely used to assess overweight and obesity, and standard cutoff values are now widely accepted for adults as well as children [26]. Apart from its inability to differentiate between fat and muscle mass, BMI does not account for ethnicity. It has been suggested that because of excessive overall adiposity at a lower body weight as compared to white, BMI may not be an accurate indicator of adiposity in Asian Indians [27]. These limitations have led to search of alternative method of estimation of total body fat. Skinfold thickness at multiple sites has also been used for estimation of total body fat in both, adults and children. Although, this is an easy and inexpensive method, discrepancies in measurements are likely if the observer is not trained and in severely obese subjects. This method, which predominantly estimates peripheral fat, may not be the best measure of adiposity in Indian children, who have a tendency to store fat centrally [19]. BIA, a simple, convenient and inexpensive method for assessing adiposity, has gained popularity in last few years. As bioelectrical resistance is based on an estimation of total body water, a further concern in children relates to uncertainty of the hydration level of fat-free mass in children at different stages of maturation [28]. DXA has gained wider acceptability for body composition studies because of its many advantages. It has been well validated for body composition assessment in children as well as infants [29, 30]. Studies have also examined the accuracy of the technique through use of carcass analysis in animal models [31].

Despite the widespread use of BMI as a screening tool for overweight and obesity in children, there is evidence that it is not a consistent predictor of percentage body fat across all ethnicities [32]. This may result in an incorrect identification of subjects at risk of adverse negative health outcomes related to excess adiposity. Recent studies have found that even at the same BMI, adults from Asia [33-36] have more body fat (as determined by DXA or four-compartment models) than do white Caucasians. Similar pattern has also been reported in children [37]. The propensity for South Asians to accumulate higher levels of body fat despite their relatively small body size has been demonstrated in adolescents [32, 38] and adults [33] and is a concern for the future health status of this ethnic group.

The magnitude of the association between childhood levels of BMI and body fatness (as determined by DXA, densitometry and other methods) have varied substantially across studies, and relatively modest ($r \sim 0.5$) associations have been reported [22]. In present study, 30.7% of boys, who had BMI in overweight category, had normal percentage body fat while 10.8% of boys from same BMI category had elevated percentage body fat. Similar figures for girls were 41.6% and 5.3% respectively. This suggests that children with BMI in overweight category are more likely to have normal body fat than elevated body fat in cases of misclassification. The proportion of children with BMI in obese category having normal body fat was very less (2.1% in boys and 0% in girls). The correlation between percentage body fat and BMI was good, but girls showed better correlation than boys (boys - r 0.76; girls - r 0.81). This correlation was best seen in subjects with normal BMI, worsened in those who were overweight (by BMI) and almost absent in obese individuals. A similar correlation between percentage body fat by DXA and BMI has also been reported previously [22, 26].

All classification cutoffs used for defining excess body fat are arbitrary and there is little agreement on the classification of excess body fat among adults or children [22]. Different studies have used different cutoffs to define excess body fat. Many studies have used prevalence matching method (method A) which seems to be more logical but depends upon the presumption of 100% agreement (exact agreement) between BMI and body fat. The other method uses cut-offs based on 85th and 95th centile (method B) for defining moderate and elevated body fat. Both of these methods use cutoffs that correspond to a critical position in a reference population but are not based on increased cardiovascular risk associated with excess body fat. In our study, we used both the above methods, and demonstrated high degree of agreement with BMI, with kappa being better with the prevalence matching method (0.62 vs 0.56). This is in agreement with previous published study from US, involving multiethnic population [22].

The shape of the percentage body fat curves is similar to expected changes in human body composition with growth [39, 40]. In normal growth and development, males gain more muscle and lean tissue at puberty, while girls gain more fat. Boys showed highest percentage body fat around 10-11 years while highest percentage body fat in girls was seen at 17 years. There were notable differences in the shape of the body fat centile curves for boys and girls. Percentage body fat in boys increased from age 7, peaked at age 10-11, and leveled off at age 14, possibly influenced by pubertal changes resulting from more muscular development than fat accumulation. The height of the peak was more pronounced for the higher centiles than lower centiles which showed less change from baseline. In contrast, the body fat centiles for girls increased more steadily from 7-17 years, with maximum rise seen in subjects in lower centiles, while higher centiles showed minimal changes. These results are in agreement with previous publications on percentage body fat curves in children and adolescents, although the techniques used for estimation were different [39, 41]

Comparing our data with NHANES showed that at lower centiles, Indian boys had lower percentage body fat whereas in higher centiles, percentage body fat was almost equal or higher. Indian girls also showed similar pattern but higher percentage body fat at higher centiles than NHANES data set. Indian children show consistently higher rise in percentage body fat accumulation with age as compared to US counterparts (visual impression of comparing two data sets). As puberty is the major physiological change occurring during this age period, indirectly, we can say that Indian children accumulate body fat during pubertal development. However, this comparison has limitations of only being age and sex matched, and not BMI or pubertal stage matched. Similar observations were also made when compared with New York pediatric Rosetta study. One of the limitations of this comparison is different time period for data collection (pediatric Rosetta study 1995-2000).

The measurement of body fat by direct method is better than assessing “fatness” with indirect methods, like BMI. However, lack of clear cutoffs for defining excess body fat makes their use limited in both research and clinical practice. The available cutoffs are not based on clinical and metabolic correlates of excess body fat. Hence, there is need to develop such cutoffs which relate excess body fat with metabolic and cardiovascular risk.

The strengths of our study are the large sample size, single ethnicity and use of DXA, a validated measure of percentage body fat in children. Although DXA is considered as the best available method but 4-compartment model is presently considered as the gold standard for estimation of body fat. The relationship between percentage body fat from DXA and percentage body fat from a 4C model has been shown to vary according to percentage body fat with DXA underestimating percentage body fat in those with lower body fat and overestimating it in those with higher body fat [42]. Williams, *et al* reported that the bias of percentage body fat measurements obtained from DXA varies according to gender, size and percentage body fat [43]. They proposed that the distribution of fat may influence the accuracy of DXA, which is of particular relevance to the Indian population as there is evidence that fat in this population is more centrally distributed than in white Caucasians [44]. Additionally, DXA shows bias across the range of fatness, whereby it under-predicted fat mass in leaner subjects and over-predicted fat mass in heavier subjects [6]. Another limitation is the small number of study subjects in 7-9 years age category, especially 8 years. However, percentage body fat of subjects in 8 years age category did not differ significantly from that of 7 or 9 years age category (P = 0.43) and showed the same pattern of change in terms of PBF.

In conclusion, we compared BMI based obesity classifications to percentage body fat classifications determined by DXA in 1,640 North-Indian children and adolescents. BMI misclassified 13-14% of boys and 11-14.5% of girls into an incorrect adiposity category. We suggest that 85th centile of percentage body fat cutoff may be used to define moderate body fat while 95th centile to define excess body fat in North-Indian children and adolescents. Comparison with percentage body fat data from two US studies showed that Indian children accumulate more body fat during peri-pubertal years.

Our study is the first large-scale study, establishing the percentage body fat distribution in apparently healthy North Indians across all age groups in childhood and adolescence.

We suggest that these data may be used for interpretation of an individual's result for decision making, for epidemiological studies and for probable use by health policy makers. These curves may be used to assess children's adiposity in both clinical and survey settings for investigating risk factors and disease outcomes.

There is an urgent need for large-scale studies which could correlate body fat in children (using percent body fat curves as shown in present study) and future risk factors for obesity-related ill health.

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