RESEARCH PAPER

Body Mass Index Cut-offs for Screening for Childhood Overweight and Obesity in Indian Children

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Objective: To develop age and sex specific cut- offs for BMI to screen for overweight and obesity in Indian children linked to an adult BMI of 23 and 28 kg/m^2 respectively, using contemporary Indian data.

Design: Cross-sectional.

Setting: Multicentric, School based.

Participants: 19834 children were measured from 11 affluent schools from five major geographical regions of India. Data were analyzed using the LMS method, which constructs growth reference percentiles adjusted for skewness.

Results: Compared to the cut-offs suggested for European populations and those by the Indian Academy of Pediatrics 2007 Guidelines, the age and sex specific cut off points for body mass index for overweight and obesity for Indian children suggested by this study are lower.

Conclusions: Contemporary cross-sectional age and sex specific BMI cut-offs for Indian children linked to Asian cut-offs of 23 and 28 kg/m^2 for the assessment of risk of overweight and obesity, respectively are presented.

Key words: *Adult equivalent BMI, Childhood, Cut-off, India, Obesity, Overweight.*

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The unabated rise in the prevalence of overweight in children and adolescents is one of the most alarming public health issues facing the world today [1]. Among Indian children, various studies report the magnitude of overweight to be from 9 to 27.5% and that of obesity from 1 to 12.9% [2-6]. Obesity increases the risk for many chronic diseases including diabetes mellitus, cardiovascular disease, and non-alcoholic fatty liver disease, and decreases the overall quality of life [7-9]. Therefore, it is imperative to identify the at risk individuals at an early stage.

Allowing for the ease of measuring height and weight in the field setting, Body Mass Index (BMI) is believed to be an acceptable indicator of the risk of overweight in children and adolescents [10]. A cut-off point of 30 kg/m^2 and 25 kg/ m^2 are recognized internationally as a definition of obesity and overweight in adults. However, BMI in children changes substantially with age, thus, age-specific cut-off points are needed. The 85th and 95th percentile have been used as cut-offs to define overweight and obesity, respectively in children [11].

The pattern of growth of a population changes over time and hence growth references should be updated regularly, particularly for countries in nutritional transition [12]. However, our multicentric growth survey on 5 to 17 year-old affluent urban Indian children show that compared to the previously available nationally representative data, boys and girls were heavier at all ages [13]. Using growth references based on a descriptive sample of a population that reflects a secular trend towards overweight and obesity may result in the underestimation of overweight and obesity. Therefore, it is crucial to find a method by which the influence of unhealthy weight on BMI reference curves is avoided.

The 85th and 95th percentile that are used as cut-off points for overweight and obesity in children are arbitrary and are not linked to obesity related health risks. Unfortunately, identifying cut-off points in children is more difficult since they have less disease related to obesity than adults. A workshop organized by the International Obesity Task Force (IOTF) proposed that adult cut-off points be linked to BMI percentiles for children to provide child cut-off points [14]. Lower BMI cut-offs of 23 and 28 kg/m^2 have been suggested for overweight and obesity for Asian adults, as they are more

prone to adiposity and central obesity at a lower BMI than their western counterparts. Thus, in the present study, we have used an external quantitative criterion, i.e. the adult BMI equivalent of 23 and 28 kg/m^2 as advised for Asian populations, to derive cut-offs for screening for risk of overweight and obesity for Indian children [15]. The specific aim of this study was to develop age and sex specific cut-offs for BMI for risk of overweight and obesity for 5-17 year old Indian children linked to an adult BMI of 23 and 28 kg/m^2, respectively using contemporary Indian data and to examine the validity of the cut-offs of 25 and 30 kg/m^2 used by western populations.

METHODS

We used data on BMI from a nationally representative, multicentric, cross sectional survey conducted from June 2007 to January 2008 [13]. The Indian Academy of Pediatrics divides India into 5 zones, i.e. North, South, East, West, and Central. We selected ten study sites from these regions (Delhi, Chandigarh, Chennai, Bangalore, Kolkata, Mumbai, Pune, Baroda, Hyderabad and Raipur). Study staff identified nutritionally well-off areas in above cities (based on per capita income) all over India and made a list of schools catering to children of socioeconomically welloff families [16]. Three schools were selected (from each zone) from those chosen by generating random numbers (yearly fees ≥ 10,000). Permission for the study was obtained from 11 schools; two schools each from in east, north, central and south zones and 3 schools from west zone participated in this study.

Standing height was measured using a portable stadiometer (Leicester Height Meter, Child Growth Foundation, UK, range 60-207cm). Weight was measured using portable electronic weighing scales (Salter, India) accurate to 100 g. Children's age was derived using school records.

Measurements were performed by 17 graduate observers acquainted with the cities and local language. They were trained as per study protocol, and given written instructions about the calibration of instruments, measurement techniques, and data entry formats. Inter-observer and intraobserver coefficients of variation were both <0.01(1%).

The cleaned data were then analyzed using the LMS method, which constructs growth reference percentiles adjusted for skewness [17]. Each growth reference is summarized by 3 smooth curves plotted against age representing the median (M), the coefficient of variation (S) and the skewness (L) of the measurement distribution [18]. The L, M, and S curves convert measurements to exact SD scores using the formula:

$$\text{SD score} = \text{Measurement} / M(t)^{L(t)} - 1 / S(t)L(t)$$

Where measurement is the child's measurement (height or weight) and L(t), M(t) and S(t) are values read from the smooth curves for the child's age *t* and sex. The models were checked for goodness of fit using the detrended Q-Q plot, Q Tests and worm plots [19].

Queries about inconsistent data were checked against the original data collection forms and obviously erroneous measurements were excluded (1.1%, *n*=221). Subjects aged <5 years or >18 years were also excluded (*n*=922), as were data where the *Z* score exceeded ± 5SD (*n*=25) [13].

Percentile curves for BMI corresponding to the 3rd, 25th, 50th, 85th and 95th percentile were constructed using the LMS method [18]. Additionally, percentile curves passing through 23 and 28 kg/m^2 at 18 years for boys and girls were constructed. The percentile curves passing through the points of 23 and 28 kg/m^2 at 18 years are the suggested cutoff points for risk of overweight or obesity in childhood.

For validating the cut-offs, a total of 250 children from schools and a tertiary care pediatric endocrine clinic were selected so that the children were distributed over the whole range of BMI categories (adult equivalent BMI of <23, 23-25, 25-28, 28-30 and >30). A total of 208 children agreed to participate in the study (mean age 11.4±2.9 years,104 boys). Children from the endocrine clinic had undergone a detailed work up to ascertain that they had no primary endocrine cause of obesity and had only nutritional obesity. All children were assessed with respect to anthropometry (weight, height, BMI and waist circumference and waist to hip ratio for abdominal obesity), blood pressure and blood parameters (fasting triglycerides, high density lipoprotein cholesterol and plasma glucose. Children were classified as normal and hypertensive according to age, gender and height [20]. As per the definition of National Cholesterol Education Program III (NCEP), children were categorized according to the number of risk factors of metabolic syndrome (MS) detected *viz.* abdominal obesity (waist circumference >90th percentile [21], hypertriglyceridemia (≥110 mg/dL), low high density lipoprotein cholesterol (≤40mg/dL), hypertension (≥90th percentile according to age, gender and height) and hyperglycemia (fasting blood glucose ≥100 mg/dL) [22]. Children were categorized as normal, having one risk (MS-1) and having ≥2 risk factors (MS>1 risk) [18]. The children were divided into five categories using the cut-offs suggested by the current study as follows: children with adult equivalent BMI of <23, 23-25, 25-28, 28-30 and ≥ 30 kg/m^2.

RESULTS

We measured 19,834 children from 11 affluent schools. After cleaning the data (removal of erroneous measurements and subjects below 5 and above 18 years of age), 18,666 children, (10,496 boys and 8,170 girls) from 5 zones of India were analyzed. ***Figure* 1** and **2** show smoothed BMI percentile curves for Indian boys and girls aged 5-17 years with the 3rd, 10th, 25th, 50th, 85th and 95th percentiles, with two additional percentiles corresponding to a BMI of 23 and 28 kg/m^2 at 18 years. BMI of 23 kg/m^2 at 18 years age in boys corresponds to the 64th percentile, and in girls to the 63rd percentile. A BMI of 28 kg/m^2 at 18 years age is on the 89th percentile in both boys and girls.

***Table* I** gives suggested age specific BMI cut-off values corresponding to adult equivalent BMI of 23 and 28 kg/m^2 at age 18 years age for Indian boys and girls. ***Fig.* 3** and ***Fig*. 4** show a comparison between the BMI cut-off's for overweight and obesity as suggested by the IAP 2007 guidelines, the CDC 2000, WHO charts, the IOTF and the present study for boys and girls. Except at five years of age, the IOTF cut-offs are highest and those suggested by the current study are the lowest.

***Figure* 4** shows the percentage of children who were normal, had one risk and had greater than one risk for metabolic syndrome in the five BMI categories (<23, 23-25, 25-28, 28-30 and >30) in the group of 208 children assessed for validating the cut-offs . While around 5% of the children with an adult equivalent BMI of less than 23 had one or more than one risk factor for MS, this percentage increased progressively with increasing BMI category (43%, 47%, 72% and 80% in the BMI category of adult equivalent BMI of 23-25, 25-28, 28-30 and >30 kg/m^2, respectively).

DISCUSSION

We have presented age and sex-specific BMI cut-offs for Indian children, based on a reference population of urban affluent children measured from June 2007 to January 2008, such that the cut-offs are linked to the adult accepted BMI of 23 and 28 kg/m^2 for overweight and obesity for Asians. The BMI values suggested by this study are comparable and at certain ages lower than those suggested by the IAP 2007 Guidelines [22] and lower than other suggested cut-offs [23-25].

With the rising incidence of childhood obesity in children the world over using the 85th and 95th percentile of the population as cut-offs for overweight and obesity is likely to result in underestimation of childhood obesity. Various methods have thus been used to avoid the influence of unhealthy weights for length/height on BMI reference curves. While constructing the WHO curves for school-age children from 5-18 years observations falling above +2 SD of the sample median for weight for height were excluded prior to constructing the charts [23]. When the CDC 2000 growth curves were developed, data from the NHANES III survey for children greater than or equal to 6 years of age were excluded from the charts for weight-for-age, weight-for-stature, and BMI-for-age as the prevalence of overweight was nearly double that seen in earlier surveys [1]. In the present study we did not use the

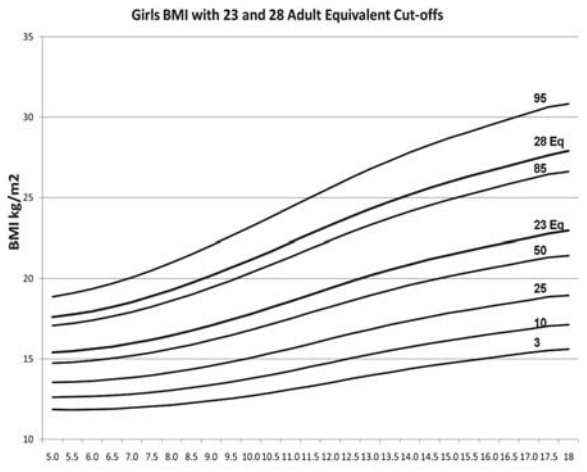

FIG. 1 *BMI percentile curves for Indian boys from 5-17 years with the 3rd, 10th, 25th, 50th, 85th and 95th percentiles, with two additional percentiles corresponding to a BMI of 23 and 28 kg/m^2 at 18 years.*

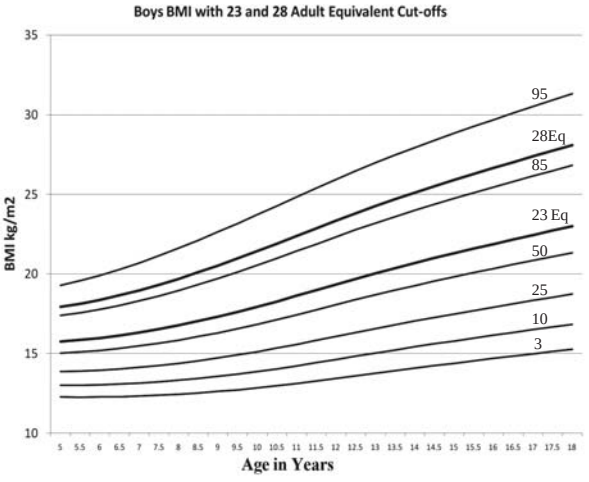

FIG. 2 *BMI percentile curves for Indian girls from 5-17 years with the 3rd, 10th, 25th, 50th, 85th and 95th percentiles, with two additional percentiles corresponding to a BMI of 23 and 28 kg/m^2 at 18 years.*

TABLE I AGE SPECIFIC BMI CUT-OFF VALUES FOR RISK OF OVERWEIGHT AND OBESITY CORRESPONDING TO ADULT EQUIVALENT BMI OF 23 AND 28 KG/M^2 AT AGE 18 YEARS FOR INDIAN BOYS AND GIRLS

	Adult Equivalent			
	BMI 23kg/m^2		*BMI 28kg/m^2*	
Age (years)	*Boys*	*Girls*	*Boys*	*Girls*
5	15.8	15.4	17.9	17.6
5.5	15.9	15.5	18.1	17.8
6	16	15.6	18.4	18
6.5	16.1	15.8	18.7	18.2
7	16.3	16	19	18.5
7.5	16.5	16.2	19.3	18.9
8	16.8	16.5	19.7	19.3
8.5	17	16.8	20.1	19.7
9	17.3	17.1	20.5	20.2
9.5	17.6	17.4	21	20.7
10	17.9	17.8	21.4	21.2
10.5	18.3	18.2	21.9	21.7
11	18.6	18.6	22.4	22.2
11.5	19	19	22.9	22.8
12	19.3	19.4	23.3	23.3
12.5	19.7	19.8	23.8	23.8
13	20	20.2	24.3	24.3
13.5	20.4	20.5	24.7	24.8
14	20.7	20.9	25.1	25.2
14.5	21	21.2	25.5	25.6
15	21.3	21.5	25.9	26
15.5	21.6	21.7	26.3	26.3
16	21.9	22	26.7	26.7
16.5	22.2	22.3	27	27
17	22.4	22.5	27.4	27.3
17.5	22.7	22.8	27.7	27.6
18	23	23	28.1	27.9

approach suggested by the WHO because the cut-off of +2 SD for weight for height is arbitrary and also for the technical reason that LMS data for calculation of SD scores for weight-for-height for children from 5-18 years by the WHO were not available. We also could not use the approach used by the CDC, as all children in the present study were measured in a time period of 8 months and omitting data from the dataset as per an arbitrary cut-off would have disturbed the regional representation of the study. Thus, we used an external criterion, adult-linked BMI, to generate BMI cut-off values for 5-17 year-old Indian children.

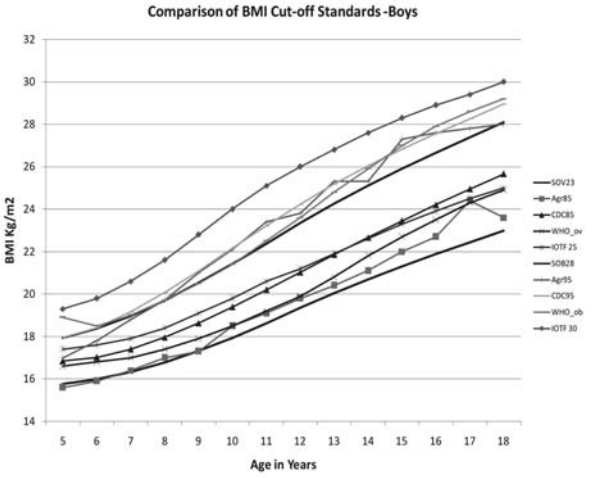

FIG. 3 *Comparative BMI cut-off's for overweight as suggested by the IAP 2007 guidelines, the CDC 2000, WHO charts, the IOTF and the present study for boys.*

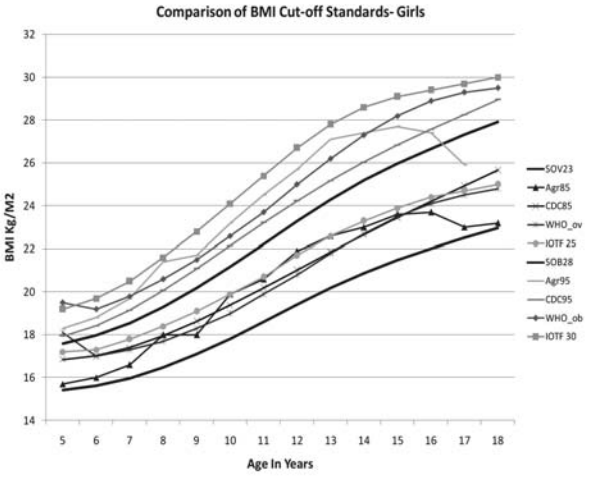

FIG. 4 *Comparative BMI cut-off's for overweight and obesity as suggested by the IAP 2007 guidelines, the CDC 2000, WHO charts, the IOTF and the present study for boys.*

To develop an internationally acceptable definition of childhood overweight and obesity that was less arbitrary and more internationally acceptable, Cole, *et al*. used six large nationally representative cross-sectional growth studies and for each survey percentile curves were drawn that at age 18 years passed through the widely used cut-off points of 25 and 30 kg/m^2 for adult overweight and obesity [26]. However, a WHO expert consultation has reviewed scientific evidence which suggests that Asian populations have different associations between BMI, percentage of body fat, and health risks compared to Europeans. They concluded that the proportion of Asians with a highrisk of type 2 diabetes and cardiovascular disease is substantial at

WHAT IS ALREADY KNOWN?

- Asian Indians are a high risk group for type 2 diabetes and cardiovascular disease at BMIs lower than the international WHO cut-off of 25 kg/m^2 for overweight and 30 kg/m^2 for obesity.

WHAT THIS STUDY ADDS?

- Age and sex-specific BMI cut-offs for Indian children from 5-17 years are presented, such that the cut-offs are linked to the adult accepted BMI of 23 and 28 kg/m^2 for overweight and obesity for Asians.

BMIs lower than the existing WHO cut-off of 25 kg/m^2 for overweight [27-29]. Studies have also indicated that body fat percentage in Indian children and adolescents as measured by bio-electrical impedance analyser and by dual emission *x*-ray absorptiometry is higher than in their Western counterparts [30]. Snehlata, *et al*. have thus suggested that a cut-off of 23 and 28 kg/m^2 be used for classifying Indian adults as overweight and obese, respectively [31]. In a study to evaluate definitions of the metabolic syndrome in adult Asian Indians Misra, *et al*., have also suggested that the BMI cut-offs be lowered to 23 kg/m^2, they additionally suggest lowering the waist circumference cut-offs to 90 cm in men and 80 cm in women, and the subscapular skinfold thickness cut-off to18 mm [32,33]. Validating the cut-offs suggested by this study on 250 children, we found that around 43% children in the adult equivalent BMI category of 23-25 kg/m^2 had ≥1 risk factor for development of the MS. Thus, if the adult equivalent of 25 kg/m^2 was used as a cut-off for overweight, these children would be misdiagnosed as normal. Similarly, around 73% children in the BMI category of adult equivalent of 28-30 kg/m^2 had ≥1 risk factor for developing the MS and would be classified as overweight rather than obese if an adult equivalent cut-off of 30 kg/m^2 were to be used.

In a study to evaluate carotid arterial stiffness in obese and healthy Indian children, Pandit, *et al*. have reported that the stiffness, pulse wave velocity and elastic modulus of the right carotid artery were significantly higher in obese and overweight children suggesting that functional changes in the carotid artery start very early in life [31]. Thus, there is a need to identify children at a risk of overweight and obesity at an early age to avoid further cardiovascular complications.

In conclusion, we have presented age and sex-specific BMI cut-offs for Indian children, based on a reference population of urban Indian affluent children, such that the cut-offs are linked to the adult accepted BMI of 23 and 28 kg/m^2 for overweight and obesity for Asians. The BMI values suggested here are likely to pick up obesity early and prevent future complications occurring due to childhood obesity.

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