RESEARCH PAPER

Impact of Using Different Growth References on Interpretation of Anthropometric Parameters of Children Aged 8-15 Years

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Objective: To compare the effect of the application of three growth references (Agarwal, 1992; Indian Academy of Paediatrics (IAP), 2015; and World Health Organisation (WHO), 2007) on interpretation of anthropometric parameters in schoolchildren.

Setting: Cross-sectional school-based study.

Participants: Children 8-15 years studying in one government school and one private school of Delhi.

Procedure: The age- and gender-specific standard deviation scores of height-for-age and BMI-for-age were estimated for each student enrolled, using the three growth references independently.

Main outcome measure: The proportion of children with short stature, thinness and overweight/ obesity determined by each growth reference were compared.

Results: A total of 1237 students participated in the study. A significantly higher proportion of children (both sexes) were classified to have short stature using WHO 2007 reference (8.8%) as compared to the Agarwal (3.3%) charts and IAP, 2015 references (3.6%). The combined prevalence of overweight and obesity was highest (34.8%) by the IAP, 2015 reference as against 32% by Agarwal charts and 29.1% by WHO, 2007 reference. Good agreement existed between the IAP, 2015 reference and Agarwal charts in classifying subjects into different BMI categories (Kappa=0.82) and short stature (Kappa=0.99).

Conclusions: In view of differences noted, use of national population derived reference data is suggested to correctly define growth trajectories in children.

Keywords: *Comparison, Growth charts, Obesity, Short stature*.

Anthropometry is the universally accepted tool for the assessment of a child's growth and nutritional status. The anthropometric parameters of an individual are interpreted by comparing with the age- and sex-matched reference data. The interpretation of an individual child's anthropometric parameters would depend upon the reference data used. Clinicians often face a dilemma on the choice of growth reference for anthropometric assessment among the different national and international growth references/ standards available. International consensus exist on the use of the World Health Organization (WHO) Child Growth Standards derived from the multi-centric growth reference study for assessing growth of children up to 5 years of age [1]. However, there is no similar multi-nation data for children beyond five years of age, and most nations use local population-derived reference data for this age group. In India, the growth reference charts developed by Agarwal, *et al*. [2] are more than two decades old. The newer Indian Academy of Pediatrics (IAP) growth references [7] for Indian children 5-18 years are based on collated national data generated during last 10 years [7]. Besides, there exist the International WHO growth reference charts for children 5-19 years of age, which are primarily based on growth of American children [8,9]. The availability and use of multiple references for clinical and research purposes can create confusion amongst healthcare providers and difficulty in correct interpretation of epidemiological and research data. A difference in prevalence of stunting, wasting, and thinness in school children from low income countries was reported on application of WHO, 2007 and NCHS growth references [10]. Similar inferences were drawn when the prevalence of overweight and obesity in school children was compared using the WHO charts, Agarwal charts and International Obesity Task Force (IOTF) growth reference charts [11].

Accompanying Editorial: Pages 115-116.

We compared the effect of the application of three different growth references; that developed by Agarwal, *et al*. [2] (Agarwal reference), IAP growth reference, 2015 [7] (IAP 2015) and the WHO growth reference [9] (WHO 2007) on estimation of proportion of school children (aged 8-15 years) classified as having short stature, thinness, severe thinness, overweight, and obesity.

METHODS

This cross-sectional study was conducted in July 2016 on schoolchildren aged 8-15 completed years, studying in 3^{rd}-10^{th} grades at two schools in northern Delhi. We selected a government and a private school to enable enrollment of children belonging to different socio-economic strata and diverse nutritional status. Children suffering from systemic illnesses or who had undergone a major surgical procedure likely to interfere with the growth, and those with obvious skeletal or neurological problem hindering evaluation of physical growth were excluded. A prior permission from school authorities was obtained. Passive parent consent and verbal student assent was also taken prior to enrollment in the study. The parents were given a patient information sheet containing the relevant details of the study and their written consent taken. The study protocol was approved by the Institutional Ethics Committee.

Prior to the start of the study, one researcher was trained to measure the bodyweight and height using standard procedures. The investigator collected the date of birth of the enrolled subjects from the school records. Using standardized equipment and techniques, the weight and height of all children fulfilling the inclusion criteria were recorded. The weight was recorded to the nearest 0.1 kg using electronic digital weighing machine without footwear and minimal clothing. Height was measured to the nearest 0.1 cm using a portable stadiometer (Seca 222; Seca GmbH & Co. Germany). Body Mass Index (BMI) was calculated by standard formula.

Using each of the three growth references - Agarwal reference [2], IAP 2015 [7] and WHO 2007 [9], age- and gender-specific standard deviation scores (SDS) of height-for-age (HFA-SDS) and BMI-for-age (BMI-SDS) were calculated for all students. Children with HFA-SDS < –2 were considered to have short stature across each of the three reference charts. Definition of thinness/obesity varies among the different references. For WHO 2007 reference, subjects with BMI-SDS <-2 were considered thin, with BMI-SDS between 1 and 2 as overweight and >2 as obese [12,13]. For IAP 2015 and Agarwal reference charts, the cutoff of BMI/age $<3^{rd}$ percentile and $<5^{th}$ percentile, respectively were used to define thinness [27]. The cutoff of BMI/age at 23rd adult equivalent (71st centile in boys and 75th centile in girls) and 27th adult equivalent (90th centile in boys and 95th centile in girls) was applied to classify overweight and obesity, respectively according to the IAP 2015 reference charts. As per the Agarwal charts, overweight and obesity were defined by the BMI /age cut off between 85th and 95th centile and >95th centile, respectively. The proportion of children with short stature, thinness, overweight or obesity obtained on applying each of the three growth references was compared.

Statistical analyses: The data was analyzed by statistical software SPSS version 20 (IBM Crop, Armonk, NY). For the purpose of statistical inference, a 2-year interval was used to show the height and BMI distribution of the subjects enrolled. The three-way ANOVA test was applied to evaluate the differences in the growth parameters between the students of the government school and private school across different age intervals on using the three different growth references. The McNemar test was applied for height variable and McNemar-Bomker test was applied for the BMI to assess the agreement between the two reference charts. A linear mixed model with suitable covariance structure on the basis of minimum Akaike's Information Criteria (AIC) was applied to compare the mean (SD) score obtained by the use of different reference charts and to assess whether mean Z score difference is influenced by gender. The Kappa statistic value was adjusted when prevalence and bias influenced the Kappa statistic. A *P*-value less than 0.05 was considered as statistically significant.

RESULTS

Of the 1256 students screened from the two schools, 1237 students (767 boys) participated in the study; 16 students were excluded because either the date of birth was unknown or the age was more than 16 years. Data pertaining to three students was removed as outliers because they were severely obese (BMI >35 kg/m^2). The proportion of students enrolled from the government school was 46.6%. The age and sex distribution, and height and BMI of the children is summarized in ***Web Table* I**. The mean SDS for height and BMI among children in government and private school across all age groups and both sexes were significantly different on application of the three growth reference charts (***Web Table* II, III**).

The mean SDS for HFA and BMI for age determined using the three growth references is given in ***Table* I**. Linear mixed model revealed no significant difference between genders among the three growth references. However, the mean SDS of HFA estimated by WHO 2007 reference was significantly lower than the Agarwal and

TABLE I Comparison of Standard Deviation Scores of Height for Age and BMI for Age of Children Aged 8-15 Years Using Three Different Growth Reference Charts (*N*=1237)

Variable	*WHO, 2007 [9]*	*Agarwal, 1992 [2]*	*IAP, 2015 [7]*
Height for age			
Girls	-0.46 (1.19)	0.45 (1.55)	0.16 (1.16)
Boys	-0.35 (1.24)	0.44 (1.23)	0.08 (1.18)
Total	-0.41 (1.22)	0.44 (1.36)	0.11 (1.17)
BMI for age			
Girls	0.07 (1.43)	0.41 (1.31)	0.25 (1.17)
Boys	-0.06 (1.68)	0.66 (1.60)	0.12 (1.15)
Total	-0.02 (1.60)	0.56 (1.50)	0.17 (1.16)

**All values in mean (SD); P<0.001 for all comparisons between WHO, 2007 [9] vs IAP, 2015 [7] and Agarwal [2] vs IAP 2015; WHO: World Health Organization; IAP: Indian Academy of Pediatrics.*

IAP 2015 references (*P*<0.001). Thus, a significantly higher proportion of children (both sexes) were classified to have short stature using WHO 2007 reference (8.8%) as compared to the Agarwal (3.3%) and IAP 2015 references (3.6%) (***Fig*. 1**). The visual comparison of distribution of height for age and BMI for age SDS among the three growth references along with the normal SDS is presented (***Web Fig*. 1** and **2**).

***Figure* 2** shows the comparison of the BMI categories in boys and girls using the three growth reference charts. Among boys, the IAP reference classified the maximum proportion with obesity (17.7%), while the Agarwal charts identified the highest proportion of overweight (20.6%) children. In girls, the IAP reference reported highest proportion with overweight (21.7%) and obesity (13.4%). The combined prevalence of overweight and obesity was highest (34.8%) by the IAP 2015 reference as against 32.0% by Agarwal charts and 29.1% by WHO2007 reference. The proportion of children (boys and girls combined) classified as obese was maximum (16.1%) by IAP 2015 as compared to 12.1% and 10.9% by Agarwal and WHO 2007 references, respectively. The IAP 2015 reference classified least proportion of children with thinness (2.4%) as compared to Agarwal reference (4.4%) and WHO 2007 reference (11.2%). The degree of agreement in classifying subjects into different BMI categories was best between the IAP 2015 and Agarwal references (Kappa=0.82), followed by WHO and Agarwal (Kappa=0.75) and least with WHO and IAP references (Kappa=0.60).

DISCUSSION

The comparative assessment of anthropometric parameters in school children using three different growth references yielded the following key observations. The low mean SDS of HFA by WHO 2007 reference resulted in classifying higher proportion of children with short stature as compared to IAP 2015 and Agarwal reference. Application of WHO 2007 reference also led to diagnosing higher proportion of children with thinness as compared to the IAP 2015 reference. Use of IAP 2015 reference accounted for a greater proportion of children classified with overweight and obesity as compared to Agarwal and WHO 2007 references. Amongst the three growth reference charts, a good concurrence existed between Agarwal and IAP 2015 references in identification of short stature, thinness, and overweight/obesity.

The primary limitation of this study was the lack of assessment of the divergent growth pattern observed in adolescents with the attainment of puberty. Also, since the objective was primarily to compare the three growth

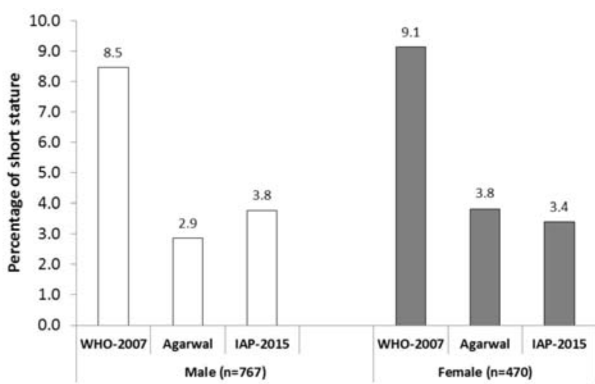

FIG. 1 *Proportion of children aged 8-15 years with short stature using three different growth reference charts.*

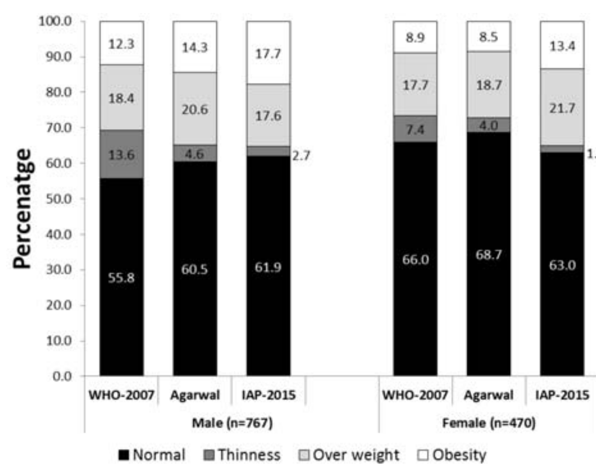

FIG. 2 *Body mass index (BMI) categories in children aged 8-15 years using three different growth reference charts.*

references, results on interpretation of anthropometric data cannot be generalized to represent nutritional status of children in this area.

The higher HFA-SDS of the subjects on application of IAP 2015 reference charts as compared to WHO 2007 reference shows that the Indian children are shorter than their Caucasian counterparts. Similar inference was drawn after the publication of the IAP 2015 growth reference charts [7,9]. Use of WHO charts will thus lead to an increase in diagnosis of short stature, creating undue anxiety among parents and unnecessary referrals to the health facility. The higher mean HFA-SDS obtained on application of Agarwal reference as compared to IAP 2015 reflects the secular trends in height in India over the past two decades, and is consistent with previous observations [15,16].

The WHO 2007 reference classified participants in lower weight strata compared to the IAP 2015 and Agarwal references. This led to diagnosing higher proportion of children with thinness by WHO references as compared to the other two references. Likewise, application of WHO 2007 references underestimated the proportion of overweight and obese children among the study group as compared to that obtained by applying IAP 2015 charts. This can lead to missing the opportunity of identifying these children and offering them appropriate screening and management. The IAP 2015 BMI centiles/Z scores are lower as compared to Agarwal *Z* scores in Agrawal charts, indicating a steep rise in obesity/overweight in recent times [6,16]. Thus, application of a similar criteria of 85th and 95th centile to define overweight and obesity as used by Agarwal, *et al.* [2] would have led to a much lower proportion of children being identified with these conditions on application of IAP 2015 reference. This has been taken care of in the IAP reference by linking the definition of overweight and obesity to adult BMI equivalent of 23 and 27, respectively. This led to lowering of cut-off for defining, and a corresponding higher detection rate of overweight and obesity by IAP 2015 reference. A rise in the weight and BMI centiles of both boys and girls on application of recent reference data from India as compared to Agarwal reference charts has been reported by Khadilkar, *et al*. [15] and Marwaha, *et al*. [6].

The present study brings out the impact of using updated national growth reference charts on interpretation of anthropometric data of older children and adolescents. We conclude that IAP 2015 growth reference remains in excellent agreement with Agarwal reference for recognition of short stature while identifying less children with short stature and more children with overweight and obesity as compared to WHO 2007 reference. This will have an impact on screening and management of children with both short stature and overweight/obesity.

Contributors: PS: execution of the study, data analysis and writing the manuscript; SG: execution of the study and writing the manuscript; RKM: contributed in execution of the study, data analysis and writing the manuscript and AS: conceptualized the paper, was overall responsible for quality of data collection and maintenance, modified and finalized the draft.
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WEB TABLE I Age and Sex Distribution and Descriptive Statistics (Height and BMI) of Subjects Studying in the Private and Government Schools

Age (years)		*Private School, mean (SD)*			*Government School, mean (SD)*	
	No. (%)	*Height (cm)*	*BMI (kg/m²)*	*No. (%)*	*Height (cm)*	*BMI (kg/m²)*
Boys						
8-10	76 (20)	136.1 (6.5)	18.05 (3.4)	74 (19)	127.7 (7.8)	15.5 (2.1)
10-12	105 (28)	144.3 (7.9)	20.4 (4.4)	99 (26)	138.8 (7.6)	15.5 (1.9)
12-14	88 (23)	158.6 (9.0)	22.1 (4.4)	138 (36)	150.1 (10.6)	17.1 (3.0)
14-16	112 (29)	167.5 (8.7)	23.0 (5.3)	75 (19)	157.7 (8.4)	17.5 (2.6)
Total	381 (100)	152.8 (14.6)	21.1 (4.9)	386 (100)	144.4 (13.7)	16.5 (2.6)
Girls						
8-10	76 (27)	135.0 (7.5)	18.6 (3.9)	49 (26)	127.2 (8.8)	15.3 (2.6)
10-12	81 (29)	145.5 (7.7)	19.7 (4.1)	45 (24)	137.0 (8.2)	15.7 (2.3)
12-14	57 (20)	155.7 (7.0)	21.4 (4.2)	75 (39)	150.0 (8.2)	17.8 (2.9)
14-16	66 (24)	158.7 (6.8)	23.2 (4.5)	21 (11)	152.6 (5.4)	16.7 (2.9)
Total	280 (100)	147.8 (11.8)	20.5 (4.5)	190 (100)	141.3 (12.8)	16.7 (2.9)

BMI: Body Mass Index; SD: Standard Deviation.

WEB TABLE II Comparison of Height Standard Deviation Scores Among Children in Government and Private School Across all Age Groups and Both Sexes

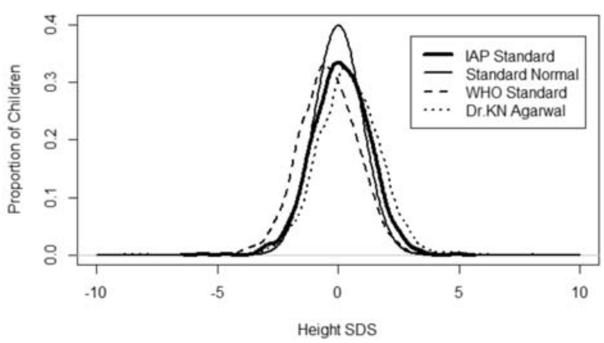
Gender	*8-10 (n=275)*		*10-12 (n=330)*		*12-14 (n=358)*		*14-16 (n=274)*	
	Pvt	*Govt*	*Pvt*	*Govt*	*Pvt*	*Govt*	*Pvt*	*Govt*
*WHO**								
Male	1.07 (0.97)	-0.47 (1.27)	0.98 (1.14)	-0.01 (1.11)	0.93 (1.04)	0.06 (1.22)	0.76 (1.21)	0.28 (1.04)
Female	1.01 (0.99)	-0.04 (1.26)	1.18 (1.72)	-0.88 (2.28)	0.79 (1.15)	-0.15 (1.27)	0.78 (1.21)	-0.28 (0.96)
Agrawal								
Male	1.07 (0.97)	-0.05 (1.27)	0.98 (1.14)	-0.01 (1.11)	0.93 (1.04)	0.06 (1.22)	0.78 (1.21)	-0.28 (0.96)
Female	1.01 (0.99)	-0.04 (1.26)	1.18 (1.72)	-0.87 (2.28)	0.79 (1.15)	-0.15 (1.27)	0.78 (1.21)	-0.28 (0.96)
*IAP**								
Mal	0.61 (0.88)	-0.45 (1.18)	0.52 (1.04)	-0.41 (1.05)	0.58 (1.07)	-0.36 (1.24)	0.60 (1.06)	-0.43 (0.98)
Female	0.60 (0.97)	-0.42 (1.19)	0.53 (1.03)	-0.74 (1.11)	0.60 (1.04)	-0.24 (1.13)	0.49 (1.02)	-0.38 (0.82)

*All values in mean (standard deviation scores); *P value <0.01; Pvt: Private school; Govt: Government school; males (n = 150), females (m=125).*

WEB TABLE III Comparison of BMI SD Score Scores Among Children in Government and Private School Across All Age Groups and Both Sexes

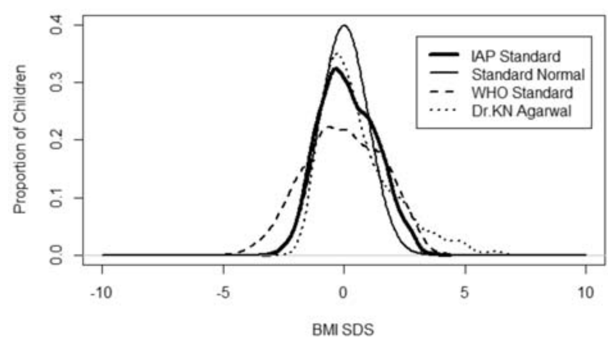
Gender	*8-10 (n=275)*		*10-12 (n=330)*		*12-14 (n=358)*		*14-16 (n=274)*	
	Pvt	*Govt*	*Pvt*	*Govt*	*Pvt*	*Govt*	*Pvt*	*Govt*
*WHO**								
Male	0.56 (1.51)	-0.61 (1.27)	1.08 (1.53)	-1.08 (1.27)	1.00 (1.39)	-0.92 (1.43)	0.61 (1.68)	-1.13 (1.21)
Female	0.66 (1.42)	-0.68 (1.05)	0.59 (1.33)	-1.01 (1.19)	0.64 (1.24)	-0.72 (1.22)	0.71 (1.25)	-0.78 (1.05)
*Agrawal**								
Male	1.27 (1.64)	0.04 (1.09)	1.63 (1.75)	-0.32 (0.73)	1.62 (1.54)	-0.12 (1.03)	1.45 (1.75)	-0.30 (0.87)
Female	1.17 (1.57)	-0.18 (1.43)	0.64 (1.15)	-0.36 (0.63)	0.73 (1.24)	-0.32 (0.83)	1.05 (1.40)	-0.45 (0.73)
*IAP**								
Male	0.56 (1.08)	-0.29 (0.86)	0.81 (1.09)	-0.65 (0.79)	0.82 (0.99)	-0.47 (0.90)	0.75 (1.17)	-0.53 (0.76)
Female	075 (1.14)	-0.34 (0.83)	0.64 (1.10)	-0.66 (0.87)	0.65 (1.08)	-0.38 (0.92)	0.86 (1.12)	-0.43 (0.79)

**P value <0.01; Pvt: Private school; Govt: Government school; males (n = 150), females (m=125).*



SDS: Standard deviation score.

WEB FIG. 1 *Comparison of distribution of height SDS among the different growth references with standard normal curve.*



SDS: Standard deviation score.

WEB FIG. 2 *Comparison of distribution of BMI SDS among the different growth references with standard normal curve.*