

Comparison of BMI Categories Using WHO 2007 and IAP 2015 Growth References Among Adolescent Girls

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ABSTRACT

Introduction: World Health Organization (WHO) 2007 growth references and Indian Academy of Pediatrics (IAP) 2015 growth references are the two most popular indices used to identify malnutrition among children and adolescents in India. However, they are not in sync in identifying malnutrition among children and adolescents. Hence, this study aimed to compare the Body Mass Index (BMI) categories based on WHO 2007 growth references and IAP 2015 growth references among adolescent girls and to associate their total body fat percentage. **Materials and Methods:** This cross-sectional study recruited 536 adolescent girls aged 10 to 15 years from private and state-run schools in Chennai, India. Height, Body Weight, and total body fat percentages were recorded. BMI-for-age z-scores were calculated. Statistical analysis included the χ^2 test, t test, and Pearson's correlation. $p < 0.05$ was considered for statistical significance. **Results:** There was a significant difference ($p < 0.001$) in the BMI categorization based on both the growth references. Thinness, as observed by WHO 2007 growth references, was four times higher than the IAP 2015 growth reference. IAP 2015 growth reference identified nearly 1/3rd of the participants to have overweight or obesity, whereas the WHO 2007 growth reference identified almost 1/4th of the participants to have overweight or obesity. The mean total body fat percentage in all categories was higher with WHO 2007 growth references categorization ($p < 0.05$). **Conclusion:** The WHO 2007 growth references over-predicted thinness and under-predicted overweight compared to IAP 2015 growth references.

Keywords: Double burden of malnutrition, Growth charts, Obesity, Thinness.

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INTRODUCTION

Adolescence is a unique juncture between childhood and adulthood. This phase marks rapid growth and development in physical, cognitive, and other domains.^[1] The adolescent population is constantly increasing, with nearly 90% living in low and middle-income countries like India.^[2] This section of the population (especially females) is at a high risk of one of the biggest global health challenges – malnutrition.^[3,4] The United Nations Decade of Action on Nutrition highlights that this decade (2016–2025) provides an unparalleled opportunity to eliminate all forms of malnutrition to achieve global nutrition and diet-related Non-Communicable Disease (NCD) targets. It is crucial to meet two critical Sustainable Development Goals (SDGs): SDG 2 (Zero hunger) and SDG 3 (Good health and well-being).^[5]

Malnutrition comprises a spectrum of conditions from undernutrition to obesity.^[6] Several growth references to identify malnutrition have been published through the years, including

Centers for Disease Control and Prevention growth references, used primarily in the American population. However, the World Health Organization (WHO) 2007 growth references and the Indian Academy of Pediatrics (IAP) 2015 growth references are the two most popular growth references used in India.^[7] Both WHO 2007 (for children and adolescents aged 5 to 19 years old) and IAP 2015 (for 5 to 18 years old Indian children and adolescents) growth references classify children and adolescents into categories of thinness, normal, overweight, and obesity based on Body Mass Index (BMI).^[8,9] Age and gender-specific cut-off percentiles of BMI are employed to compute BMI-for-age z-scores (BAZ). To account for the Asian Indian ethnic group, the IAP 2015 growth reference uses the adult equivalent of 23 and 27 kg/m² cut-offs to define overweight and obesity.^[10]

Although BAZ is age and gender-specific, they do not account for Total Body Fat percentage (TBF%) and skeletal muscle percentage in adolescents.^[11] A higher TBF% is a risk factor for metabolic conditions. Hence, it is essential to recognize levels of adiposity associated with various BMI categories.^[12] Therefore, this study aimed to compare the BMI categories based on the WHO 2007 growth reference and IAP 2015 growth reference among adolescent girls aged 10 to 15 years and to associate this with their body fat percentage.



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MATERIALS AND METHODS

Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guideline is used to report this cross-sectional study. Ethical approval was obtained from the Institutional Ethics Committee and the protocol was registered with the Clinical Trials Registry of India. The multistage sampling method used in the study included stratified random sampling to select corporation (state-run) and private schools from the east, west, north, south, and central zones of Chennai city. Schools were selected after obtaining permission from the authorities of the respective institutions. From a previous study on the prevalence of malnutrition among 10 to 19-year-old adolescents in India, a sample size of 520 was calculated with a 95% confidence interval at 14.4% estimated proportion and 10% design effect.^[13] Purposive sampling was used to select 536 adolescent girls aged 10 to 15 from the selected schools. Written informed consent and assent were obtained from parents and the participants, respectively.

Height, Body Weight, and TBF% were measured for all the participants. Height and Body Weight were measured using a stadiometer and an electronic scale (Omron: HBF-701 Karada scan). Height was measured to the nearest 0.1 cm, and Body Weight was measured to the nearest 100 g. BMI was calculated using the formula $\text{BMI (kg/m}^2\text{)} = \text{Weight (kg)} / \text{Height (m}^2\text{)}$. A handheld Bioelectric Impedance Analyzer (Omron: HBF-701 Karada scan) was used to measure TBF%. All measurements were made by the corresponding author to reduce bias.

This study compared two growth references: WHO 2007 growth references and IAP 2015 growth references. Both are age and gender-specific and can be expressed in standard Deviation (SD) units (z-scores) from the central tendency of the reference population. For WHO 2007 growth references, BAZ was calculated via the WHO AnthroPlus software. According to this, for both boys and girls, the following BAZ correspond to the respective categories:^[14]

- i. $\geq +2$ SD = obesity,
- ii. $\geq +1$ SD and $< +2$ SD = overweight,
- iii. $< +1$ SD and > -2 SD = normal,
- iv. ≤ -2 SD = thin. The IAP 2015 growth references highlight different z-score cut-offs for boys and girls, and were calculated via the AnthroCal App. For girls, BAZ corresponds to the following categories:^[15]

- i. $\geq +1.64$ SD = obesity,
- ii. $\geq +0.67$ SD and $< +1.64$ SD = overweight,
- iii. $< +0.67$ SD and > -2 SD = normal,
- iv. ≤ -2 SD = thin.

Data Analysis

Categorical variables are presented as frequencies and percentages. Continuous variables are presented as mean (SD). The chi-square test was used to compare the classification of adolescents based on BMI categories between IAP 2015 and WHO 2007 growth references. An independent t-test was used to understand the differences in BAZ and mean TBF% among various BMI categories as categorized by WHO 2007 and IAP 2015 growth references. Pearson's correlation was used to study the association between mean TBF% and BAZ (as calculated by WHO 2007 and IAP 2015 growth references). Data was analyzed using Jamovi (version 2.3.28). p value < 0.05 was considered statistically significant.

RESULTS

Of the 536 participants, 281 (52.42%) adolescent girls were from state-run schools, while 255 (47.58%) belonged to private schools. The mean age of the participants was 12.23 (1.21) years. Mean height, Body Weight, BMI, and TBF% of the participants were found to be 147.96 (8.15) cm, 42.34 (12.29) Kg, 19.10 (4.39) kg/m^2 and 22.18 (5.38)%, respectively.

BMI categories of adolescent girls are presented in Figure 1. Based on both WHO 2007 and IAP 2015 growth references, significant differences were observed between adolescent girls from private and state-run schools, and more participants from private schools were found to have overweight and obesity. The proportion of thinness was nearly double among adolescent girls from state-run schools as compared to adolescents from private schools. There was a significant difference ($p < 0.001$) in the percentage distribution of adolescent girls based on IAP 2015 and WHO 2007 growth references. The WHO 2007 growth references categorized four times more participants as thin, whereas more participants were classified into categories of normal, overweight, and obesity according to IAP 2015 growth references. Interestingly, IAP 2015 growth references classified nearly 1/3rd of the participants into categories of overweight or obesity, whereas the WHO 2007 growth references classified almost 1/4th of the participants into categories of either overweight or obesity.

The mean BAZ was significantly higher when calculated by WHO 2007 growth references compared to IAP 2015 growth references for thin, overweight and obesity categories ($p = 0.004$). There was no significant difference in the mean TBF% between adolescent girls from private and state-run schools.

Table 1 indicates the mean TBF% of various BMI categories as classified by IAP 2015 and WHO 2007 growth references. There was a significant difference in the mean TBF% among adolescents classified as thin, normal, and overweight. A significant association was observed between mean TBF% and BAZ as calculated by IAP 2015 growth references ($r = 0.75$, $p < 0.001$) and WHO 2007 growth references ($r = 0.73$, $p < 0.001$).

As depicted in Table 2, according to the WHO 2007 growth reference, most participants categorized as thin had TBF% in the first quartile, but a few had TBF% in higher quartiles. The majority from the normal category had TBF% in the second and third quartiles, however, 13.62% and 3.92% belonged to the first and fourth quartiles, respectively. As per the IAP 2015 growth reference, almost all participants categorized as thin had TBF% in the first quartile. The majority from the normal category had TBF% in the first and second quartiles, however, 16.04% and 2.98% belonged to the third and fourth quartiles, respectively. Based on both the growth references, most participants with overweight and obesity had TBF% in the third and fourth quartile, although a few of them had lower TBF%.

DISCUSSION

The WHO 2007 growth references identified more adolescents as “thin”, compared to IAP 2015 growth references. As per the IAP 2015 growth references, more adolescents were observed to have overweight and obesity as compared to the WHO 2007 growth references. Similar trends have been seen in studies conducted in other parts of India.^[16,17] While the percentage of adolescents with thinness remained roughly the same, the percentages of overweight and obesity have shown a considerable increase over the years. Studies have shown that in urban settings, factors

contributing to an obesogenic environment are higher.^[18-20] A research study conducted by Saikia *et al.* (2018) in the northeast part of the country also reported the combined prevalence of overweight and obesity among adolescents to be around 30%.^[21]

Mean BMI and TBF% were similar to that observed in cross-sectional studies conducted among adolescents in different parts of India, such as Mysore and Dibrugarh.^[20,21] The constant rise in BMI or BAZ among Indian adolescent girls can also be attributed to the increase in TBF% and is a cause of serious concern. TBF% had a significant positive correlation with both IAP 2015 and WHO 2007 growth references, as also observed in similar studies.^[21] The anthropometry of Indian adolescents is different than their Caucasian counterparts due to genetic factors. Additionally, growth references need to be updated constantly to account for rapid economic and social transition in a developing country like India. Therefore, Indian growth references may be more appropriate to assess malnutrition among Indian adolescent girls in comparison to Western growth references, which may not capture the true picture.^[22]

This article adds to the literature by comparing two popular growth references used in India among adolescent girls from private and state-run schools and associating them with TBF%. The study reinforces that more recent and nation-specific growth references are better indicators in identifying malnutrition

Table 1: Mean Total Body Fat Percentage of Participants Based on BMI Categories (n=536).

BMI Categories	Total body fat percentage Mean (SD)		p value
	WHO 2007 growth references classification	IAP 2015 growth references classification	
Thin	17.05 (4.31)	14.68 (2.51)	0.014
Normal	20.98 (4.09)	20.03 (4.09)	<0.001
Overweight	26.89 (3.22)	25.64 (3.54)	0.004
Obesity	29.55 (4.41)	29.11 (3.98)	0.29

BMI, Body Mass Index; WHO, World Health Organization; IAP, Indian Academy of Pediatrics. Note: Results computed from *t*-test.

Table 2: BMI Categories as Per Total Body Fat Percentage Quartiles (n=536).

Body fat percentage quartiles	BMI Category							
	WHO 2007 growth reference				IAP 2015 growth reference			
	Thin n (%)	Normal n (%)	Overweight n (%)	Obesity n (%)	Thin n (%)	Normal n (%)	Overweight n (%)	Obesity n (%)
Q1 <18.58%	55 (10.26)	73 (13.62)	3 (0.56)	3 (0.56)	17 (3.17)	108 (20.14)	5 (0.93)	4 (0.75)
Q2 18.50-22.10%	12 (2.24)	119 (22.20)	4 (0.75)	0 (0.00)	0 (0.00)	129 (24.07)	5 (0.93)	1 (0.19)
Q3 22.10-25.90%	4 (0.75)	109 (20.34)	20 (3.73)	3 (0.56)	1 (0.19)	86 (16.04)	45 (8.40)	4 (0.75)
Q4 >25.90%	4 (0.75)	21 (3.92)	69 (12.87)	37 (6.89)	0 (0.00)	16 (2.98)	54 (10.07)	61 (11.39)

BMI, Body Mass Index; WHO, World Health Organization; IAP, Indian Academy of Pediatrics.

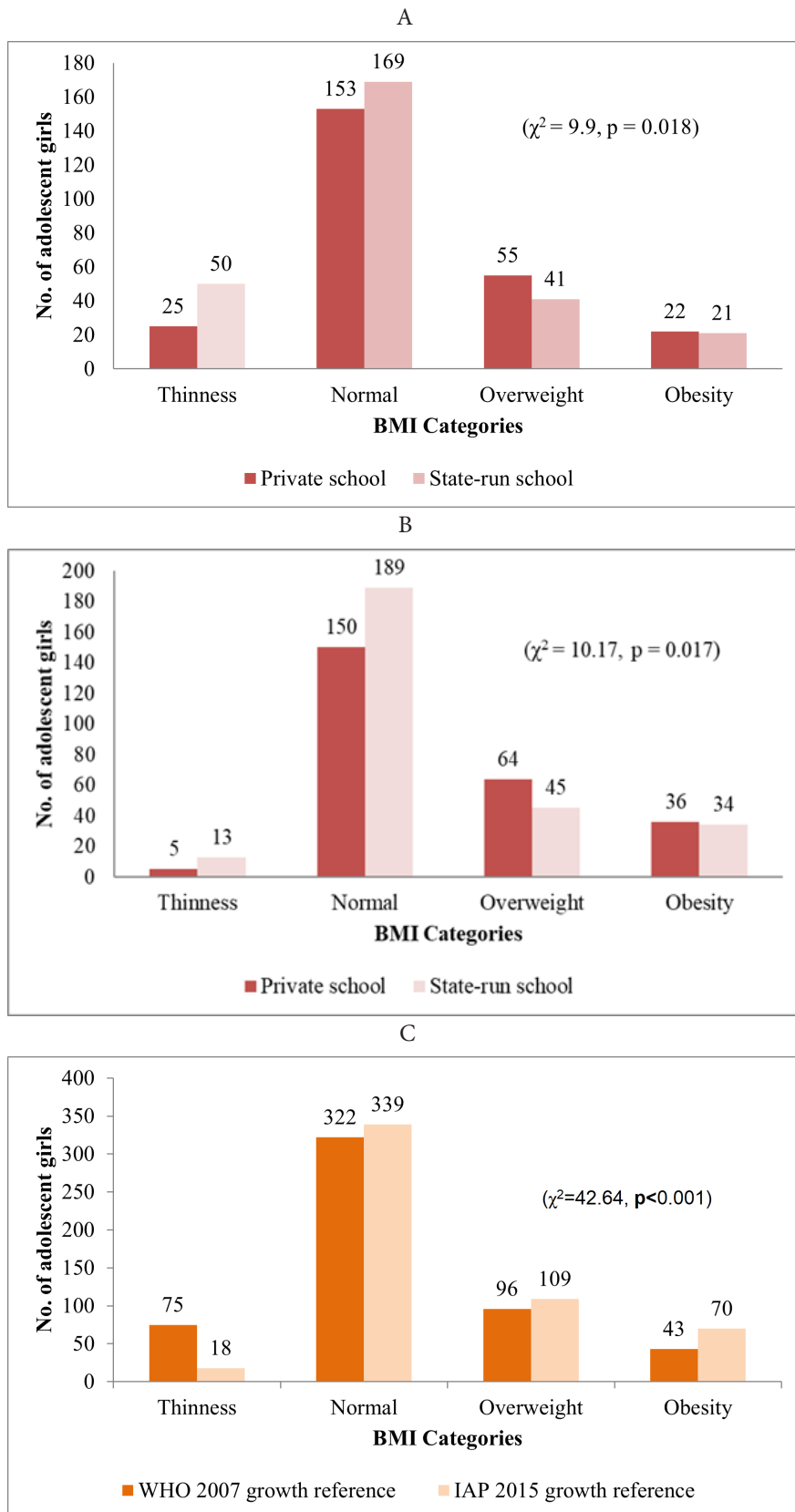


Figure 1: BMI categories of adolescent girls (A) based on WHO 2007 growth reference (B) based on IAP 2015 growth reference (C) as categorized by WHO 2007 and IAP 2015 growth reference. BMI, Body Mass Index; WHO, World Health Organization; IAP, Indian Academy of Pediatrics; χ^2 , chi-square test.

among Indian adolescent girls. The strength of this study lies in the measurement of TBF% and in studying the differences in BMI between adolescent girls from private and state-run schools. A similar study can be performed among male adolescents to understand if comparable patterns are observed.

CONCLUSION AND SUMMARY

WHO 2007 growth references over-predict thinness and under-predict overweight and obesity in comparison to IAP 2015 growth references. However, it is important to assess TBF% to understand the degree of adiposity among the participants. The overall proportion of adolescent girls with either overweight or obesity is much higher than those with thinness. The prevalence of overweight adolescent girls is higher in private schools, whereas thinness prevails more in state-run schools. It is crucial to correctly identify both forms of malnutrition, either thinness or overweight/obesity, as early as possible, to take the necessary corrective action. It might also be interesting to use IAP 2015 growth references in classifying children and adolescents of Indian origin currently residing outside India. This might let the health worker to identify risk of overweight or obesity corresponding to the adult equivalent of 23 and 27 kg/m² cut-offs for Asian Indian population, which might go unnoticed via WHO 2007 growth references.

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CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

FUNDING STATEMENT

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ABBREVIATIONS

BAZ: BMI-for-age z-scores; **BMI:** Body Mass Index; **IAP:** Indian Academy of Pediatrics; **NCD:** Non-Communicable Disease; **SD:** Standard Deviation; **SDGs:** Sustainable Development Goals; **STROBE:** Strengthening the Reporting of Observational Studies

in Epidemiology; **TBF%:** Total Body Fat Percentage; **WHO:** World Health Organization.

ETHICAL APPROVAL

Ethical approval was obtained from the Ethics Committee of Women's Christian College, Chennai, India (Protocol No.: WCC/HSC/IIEC-2021:239 dated 23-11-2021). This study is registered with the Clinical Trials Registry of India (CTRI/2022/02/040501, Registered on 22/02/2022). The procedures used in this study adhere to the tenets of the Declaration of Helsinki.

CONTRIBUTION DETAILS

Both authors contributed to the study's conception and design. Material preparation, data collection and analysis were performed by Ms. D. Dimple. The first draft of the manuscript was written by Ms. D. Dimple and both authors commented on previous versions of the manuscript. Both authors read and approved the final manuscript.

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