Comparison of various body fat indices in early and mid-adolescents of South India: School-based cross-sectional study

Ayyavoo Selvi[1], Sridevi A Naaraayan[2], Dorairaj Priyadharishini[2], N Shajathi Begum[2]

From [1]Department of Pediatrics, Stanley Medical College, [2]Department of Pediatric, Institute of Child Health and Hospital for Children, Chennai, Tamil Nadu, India

Correspondence to: Dr. Sridevi A Naaraayan, A-5, Sriniketan Apartments, 12 and 13, Gengu Reddy Road, Egmore, Chennai – 600 008, Tamil Nadu, India. Phone: +91-9884279417. E-mail: childdoctorsri@yahoo.co.in

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ABSTRACT

Background: The most important bottleneck in the management of obesity is a lack of a gold standard measuring tool. Although body mass index (BMI) is the most commonly used index to identify obesity, other indices such as waist circumference and skinfold thickness are more specific in measuring fatness. **Objective:** The objective of the study was to determine the agreement between BMI, waist circumference, and triceps skinfold thickness (TSFT) against body fat percentage calculated using 7-site skinfold thickness in South Indian adolescents. **Methods:** This cross-sectional study was performed in selected government-run schools in Chennai from May 2016 to October 2016. Schoolchildren of age 10–16 years without any medical illness which are known to cause discordant body proportions were included in the study. Sample size was fixed at 700. Date of birth, gender, and the anthropometric parameters, namely, height, weight, waist circumference, and skinfold thickness at triceps, chest, axilla, abdomen, thigh, subscapular, and suprailiac regions were measured by standard procedure and noted. Body fat percentage was calculated from 7-site skinfold thickness using Jackson-Pollock formula. Participants were classified as obese and non-obese based on BMI, waist circumference, TSFT, and body fat percentage using appropriate standards. Agreement between various indices was determined using Cohen's kappa statistic. **Results:** BMI, waist circumference, and TSFT showed moderate agreement with body fat percentage calculated from 7-site skinfold measurement. BMI and TSFT showed substantial agreement (k=0.608 for BMI and k=648 for TSFT) with body fat percentage in girls and only fair agreement (k=0.366 for BMI and k=0.291 for TSFT) in boys. Waist circumference showed moderate agreement with body fat percentage in boys (k=0.523) and girls (k=0.575). **Conclusion:** BMI, waist circumference, and TSFT show moderate agreement with body fat percentage calculated from 7-site skinfold measurement in South Indian adolescents. Measurement of waist circumference is recommended to classify an adolescent as obese, especially boys.

Key words: *Adolescents, Agreement, Body fat, Body mass index, Waist circumference*

Obesity is accumulation of excess body fat to the extent that it may have an adverse effect on health [1]. Obese children are more likely to become obese adults, and the biological changes that lead to obesity-related cardiometabolic disease start developing in childhood [2]. Hence, childhood obesity is considered the most serious public health challenge of this century [3]. A first and most important roadblock in the management of obesity is the lack of a gold standard measuring tool [4]. Body mass index (BMI) is the most commonly used index to identify obesity [5]. Although other indices such as waist circumference and skinfold thickness are more specific in measuring fatness, they are cumbersome and require periodic training of health personnel [6]. From skinfold measured in multiple sites (three/five/seven), Jackson and Pollock formula can be applied to calculate percentage of body fat [7]. Dual-energy X-ray absorptiometry (DEXA) is frequently used as the reference standard to assess the body composition in children [8], but its complexity and cost limit its use in daily clinical practice, and hence it still remains a tool confined to research.

It is now well established that Asian adults, adolescents, and children have different body composition compared to Europeans. The objective of this study was to compare the extent of agreement between BMI, waist circumference, and triceps skinfold thickness against body fat percentage calculated using 7-site skinfold thickness in South Indian early and mid-adolescents.

MATERIALS AND METHODS

This cross-sectional study was performed in selected government schools in Chennai, which come under school health program of the institution, from May 2016 to October 2016. The study was commenced after approval from the Institutional Ethics Committee. Permission was obtained from school authorities concerned. Written informed consent was obtained from parents and assent from children. Schoolchildren aged 10–16 years, who assented,

were included in the study. Children, with medical conditions which are known to cause discordance in body proportions such as skeletal dysplasias and genetic syndromes, were excluded from the study. Sample size was fixed at 700 based on kappa value of previous study, allowing for error margin of 5% [9].

To start with, correct date of birth and gender were noted. All anthropometric measurements were made by two observers of either sex. Each observer recorded all the anthropometric parameters of children belonging to their sex. Height was measured using portable wall-mounted stadiometer to the nearest millimeter, with the child standing erect without shoes. Weight was measured using electronic weighing scale to nearest gram with the child wearing light clothing. BMI was calculated using the formula weight (kg)/height $(m)^2$. Waist circumference was measured using a non-stretchable tape to the nearest millimeter, midway between lower costal margin and iliac crest [10]. Triceps skinfold thickness (TSFT) was measured using Harpenden caliper along midline in back of arm, midway between acromion and olecranon. Skinfold thickness was also measured in six other sites, namely, chest, subscapular, midaxillary, abdomen, suprailliac, and thigh by standard procedure [11].

Body fat percentage was calculated using Jackson-Pollock formula

Male: $1.112 - (0.00043499 * s) + (0.00000055 * s^2) (0.00028826 * a)$

Female: $1.097 - (0.00046971 * s) + (0.00000056 * s^2) (0.00012828 * a)$

Where s = sum of 7 skinfold in millimeter and a = age [12,13].

For the purpose of analysis, all anthropometric parameters were interpreted as two categories, obese and non-obese. BMI was interpreted using sex-specific IAP growth chart, wherein children falling above 23 adult equivalent centile were classified as obese and those below were classified as nonobese [14]. Waist circumference was interpreted using Khadilkar standards; waist circumference more than 90^{th} centile which is considered high risk was classified as obese [15]. Triceps skinfold thickness was interpreted using Khadilkar standards; TFST more than 75^{th} centile was classified as obese [16]. Body fat percentage more than 25% in boys and 32% in girls was considered obesity [12,13]. Statistical analysis of data was performed by statistical software – SPSS Version 21. Qualitative parameters were expressed in proportions. Outcome variables were categorized as normal or abnormal and their prevalence was expressed as a percentage. Prevalence of outcome variable by various methods was compared using Cohen's Kappa statistics. 95% confidence interval for Kappa statistic was calculated using the formula $\kappa \pm 1.96$ SE. Kappa value of 0 is considered nil agreement, 0.01–0.20 slight agreements, 0.21–0.40 fair agreements, 0.41–0.60 moderate agreements, 0.61–0.80 substantial agreements, and >0.81 almost perfect agreement [9].

RESULTS

A total of 700 students of age 10–16 years from five different government schools were included in the study. The age and sex distribution of the children is shown in Table 1. Mean (standard deviation) age was 12.85 (1.96) and male-to-female ratio was 1:1.07. Nearly 37% belonged to lower middle and 63% to upper lower socioeconomic strata as per Kuppuswamy scale. The prevalence of obesity based on various indices is depicted in Fig. 1.

While comparing the prevalence of obesity according to BMI and body fat percentage, it was observed that, of 82 children classified as obese and overweight by BMI, only 39 (48%) were classified as obese by body fat percentage as well. Similarly, out of 618 classified as non-obese by BMI, 606 (98%) were classified as non-obese by body fat percentage as well. A total of 645 (92%) participants are in concordance and 55 (8%) are in discordance. The agreement between various indices, as given by kappa statistic, is shown in Table 2. All three indices showed moderate agreement with body fat percentage.

The agreement of all three indices with body fat percentage was done age wise and did not reveal any specific pattern. The agreement between the indices was analyzed sex wise and the results are shown in Table 3. It can be observed that in boys, BMI and TSFT had only fair agreement with body fat percentage, whereas waist circumference had a moderate agreement. In girls, both BMI and TSFT had substantial agreement with body fat percentage while waist circumference showed only moderate agreement.

DISCUSSION

Overall, this study revealed a moderate agreement between the three indices, namely, BMI, waist circumference, and TSFT with

Table 1: Age and sex distribution

Age	n (%)		Total
	Male	Female	
10	47 (44)	59 (56)	106
11	54 (51)	51 (49)	105
12	59 (57)	45 (43)	104
13	52 (49)	55 (51)	107
14	40 (40)	60 (60)	100
15	44 (44)	57 (56)	101
16	42 (55)	35 (45)	77
Total	338 (48)	362 (52)	700

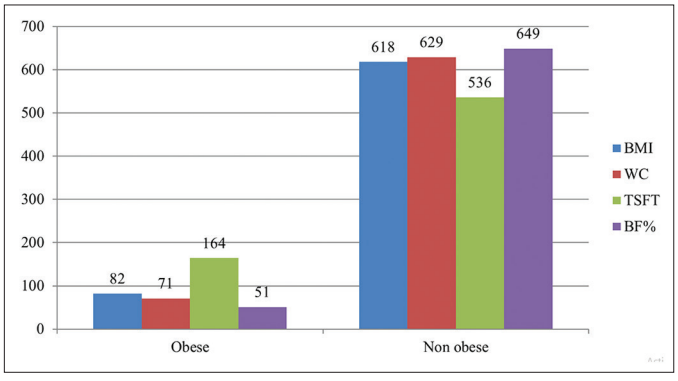

Figure 1: Prevalence of obesity based on various indices

Table 2: Agreement of various indices with body fat percentage

Comparison	Kappa value	95% confidence interval	Interpretation
BMI versus body fat	0.55	0.44–0.65	Moderate agreement
Waist circumference versus body fat	0.59	0.48–0.69	Moderate agreement
TSFT versus body fat	0.54	0.44–0.65	Moderate agreement

TSFT: Triceps skinfold thickness, BMI: Body mass index

Table 3: Sex-wise agreement of various indices with body fat percentage

Comparison	Boys		Girls	
	Kappa value	Agreement	Kappa value	Agreement
BMI versus body fat %	0.366	Fair	0.608	Substantial
Waist circumference versus body fat%	0.523	Moderate	0.575	Moderate
TSFT versus body fat%	0.291	Fair	0.648	Substantial

TSFT: Triceps skinfold thickness, BMI: Body mass index

body fat percentage. In girls, there was substantial agreement between BMI and body fat percentage, whereas, in boys, there was only a fair agreement between BMI and body fat percent, while waist circumference had a better agreement. Main limitation of the study is that the participants were limited to middle and lower socioeconomic strata, while the higher socioeconomic groups were unrepresented. Further, body fat was interpreted based on single cutoff given in the Western literature. Age- and sex-wise Indian reference standards are not available. DEXA, which is the reference standard, was not performed in this study and the scope of the study was limited to a comparison of the given indices.

Moderate agreement between BMI and body fat percentage determined by multiple sites skinfold thickness measurements has been reported by previous studies [9]. Similar moderate agreement between BMI and body fat percentage measured by DEXA has also been reported [17]. Hence, BMI is considered an acceptable approximation of total body fat and still remains the most commonly used anthropometric index used to assess obesity [5]. However, American Academy of Pediatrics policy statement cautions that when using BMI, "clinical judgment must be used when applying these criteria to a patient because obesity refers to excess adiposity rather than excess weight, and BMI is a surrogate for adiposity" [18]. This discordance between weight and adiposity is due to the fact that BMI does not distinguish between fat mass and lean mass. This means that body fat calculated using BMI can be underestimated in older subjects because of their differential loss of lean mass and decreased height and overestimated in subjects with a muscular build such as athletes and boys [19]. As a consequence, BMI is a less reliable indicator of adiposity in boys when compared to girls.

Previous Western studies have shown that TSFT may be the best screening tool for adiposity in boys while abdominal and thigh skinfold measurements are best predictors of body fat in girls [20,21]. However, our study revealed only a fair agreement between TSFT and body fat percentage in boys. This is probably due to racial differences in patterns of accumulation of fat, wherein Asians have a tendency to central adiposity. Besides directly reflecting central adiposity, waist circumference is also an indicator of visceral adiposity and cardiometabolic risk. Hence, there are recommendations to include waist circumference in addition to BMI to assess obesity [22]. The previous study has established that, among the three indices, waist circumference has the highest specificity in identifying obesity [23]. Further, measurement of waist circumference is less cumbersome than measurement of skinfold thickness and does not require any special equipment.

CONCLUSION

On the whole, BMI, waist circumference, and TSFT show moderate agreement with body fat percentage in South Indian adolescents. In girls, BMI shows substantial agreement with body fat percentage, while in boys, BMI has only fair agreement, and waist circumference has a better agreement with body fat percentage. Hence, we recommend the inclusion of waist circumference in addition to other routine anthropometric measurements such as height, weight, and BMI to assess nutritional status of South Indian adolescents.

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