Original Research Article

VALIDATION OF ANTHROPOMETRIC SCREENING MEASURES FOR IDENTIFYING OVERWEIGHT AND OBESITY AMONG SCHOOL-AGED CHILDREN IN SOUTH INDIA: A CROSS-SECTIONAL STUDY

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ABSTRACT

Background: Reliable, low-cost screening tools for identifying childhood overweight and obesity are essential in low- and middle-income countries, where resource constraints limit the use of advanced body composition techniques. Although body mass index (BMI) is widely used, its limitations in distinguishing fat mass from lean mass have prompted interest in alternative anthropometric indicators. **Objective:** To evaluate the validity of mid-upper arm circumference (MUAC) and mid-thigh circumference (MTC) as screening measures for overweight and obesity among School children aged 6–12 years, using BMI-for-age Z-scores as the reference standard.
Materials and Methods: A cross-sectional study was conducted in Perambalur district from April 2023 to March 2024. A total of 532 children were included, and their anthropometric measurements were measured. Pearson's correlation coefficients were used to assess the associations between BMI and alternative measures. Receiver operating characteristic (ROC) curve analysis was performed to determine the discriminatory ability and optimal cut-off values of MUAC and MTC for identifying overweight and obesity. p-value <0.05 was considered statistically significant.
Results: The study found a strong positive correlation between BMI and MUAC (r=0.864 in females, r=0.875 in males) and MTC (r=0.825 in females, r=791 in males). ROC analysis indicated that MUAC had high discriminatory accuracy for males and MTC for both genders in discriminating obesity, with high sensitivity and specificity, and an AUC of more than 0.9 for these measures.
Conclusion: MUAC and MTC exhibit strong agreement with BMI-based weight status classification and demonstrate high screening accuracy for identifying overweight and obesity among school-aged children. These simple, non-invasive measures may complement BMI in large-scale screening programs, particularly in resource-limited settings. Further validation against direct measures of adiposity and in diverse populations is warranted.
Keywords: MUAC, MTC, BMI, Obesity, Overweight

INTRODUCTION

Globally, the prevalence of childhood obesity has emerged as a potential public health problem, particularly in children aged 6-12 years. The World Health Organization (WHO) estimated that around 40 million children were categorized as overweight and obese in 2023, with a higher prevalence being contributed in developed and developing countries.[1] The global prevalence of childhood obesity ranges from 10 to 15%, higher in American regions (30%) to less than two percent in the African regions. This rising prevalence of childhood obesity poses an urgent and major challenge to healthcare delivery globally.[2] In India, since 2010, there has been a gradual rise in childhood obesity, mainly due to rapid urbanization, sedentary lifestyles, and dietary modification, including increased intake of fast food/packaged food.[3-9] In India, several studies have reported a prevalence of obesity and overweight of approximately 12%-22%, particularly in school-going children, emphasizing the need for early identification and intervention to limit the growing burden of overweight and obesity.[3-7] Among the anthropometry indices, the Body Mass Index (BMI) is the most used indicator for assessing overweight and obesity in children due to its ease of measurement and reliability.[6,7] However, it has certain limitations reported while measuring in children, such as its failure to differentiate between fat mass and lean body mass.[8] These constraints have driven interest in alternative anthropometric measures, such as Mid-Upper Arm Circumference (MUAC) and Mid-thigh Circumference (MTC), which may offer practical advantages in population-based screening.

MUAC is an easily measurable and well-recognized anthropometric indicator that has been conventionally used to measure malnutrition in children, including overweight and obesity in resource-limited settings.[9-13] Several studies in India documented a positive correlation and discrimination between BMI and MUAC, emphasizing its utility as a reliable, simple, and practical screening tool for measuring malnutrition among children.[6-7,14] The Mid-Thigh Circumference (MTC) is another anthropometric parameter that has shown strong correlations and discrimination with BMI and body fat percentage. MTC reflects both muscle and fat distribution in the lower limbs and is considered a valuable indicator for detecting obesity in children. An Indian study has demonstrated that MTC has a higher correlation with BMI compared to other regional anthropometric measures, making it an important tool for discriminating against childhood obesity.[14] Understanding the validity of BMI, MUAC, and MTC is essential for developing comprehensive screening strategies, particularly in school settings where large-scale obesity assessments are required. These anthropometric measurements are practical and cost-effective and can be used in resource-poor settings, making them ideal for early detection of childhood obesity. This study aimed to evaluate the validity of MUAC and MTC as screening measures for overweight and obesity among School children aged 6–12 years, using BMI-for-age Z-scores as the reference standard.

MATERIALS AND METHODS

Study Design and Setting

A school-based cross-sectional study was conducted between April 2023 and March 2024 in Perambalur district, Tamil Nadu, India.

Study Participants

One school was randomly selected from the list of six eligible schools in the Perambalur district. Children aged 6–12 years with written parental consent were eligible for the study. Those with chronic illnesses or physical conditions affecting anthropometric measurement were excluded.

Sample Size

The sample size was calculated using $n = Z^2 * p * q / d^2$. Where n is the sample size, Z is the standard normal deviation (1.96 for a 95% confidence interval), p is the prevalence, q is (1-p), and d is the allowable error (precision). The prevalence of obesity was 13% [7], with a 3% margin of error (d = 0.03) and a 95% confidence interval; the calculated sample size was 482. Considering a 10% non-response rate, the final sample size was rounded up to 532 to ensure adequate representation of the study population.

Sample Selection

A complete list of students willing to participate, enrolled from 1st to 6th standard, with the 6 to 12 years age category, constituted the sampling frame. From each age group, 76 students were selected through Simple Random Sampling (SRS) using the sampling frame. Students who were absent on the day of measurement were revisited the next day; persistent non-availability was treated as non-response, and the next number by SRS was included for the study.

Data collection procedure

The study received ethical approval from the Institutional Ethics Committee (IEC), and permission was obtained from the concerned school principal prior to the commencement of the study. Parents were informed about the study's purpose, and written informed consent was obtained. A semi-structured questionnaire was used to assess the basic characteristics, including age and gender, of the students. Anthropometric data were collected by the principal investigators using the WHO standard protocol [15]. Body weight was measured using a digital weighing scale (brand: Omron; accuracy: ±100 g), calibrated daily before use. Height was recorded using a portable folding stadiometer (brand: ABS plastic Portable Stadiometer SF00001506, 20 - 210 cm; accuracy: ±0.1 cm) with children standing barefoot in the Frankfurt plane. Two readings were taken for each parameter, and the mean value was used for analysis. Any discrepancy greater than 0.3 kg for weight or 0.5 cm for height prompted a third measurement. All instruments were operated by the principal investigator, who underwent a one-day standardization and inter-observer reliability training before data collection. Using weight and height measurements, BMI (kg / m^2) was calculated [15]. The WHO BMI for age chart (5-19 years) was used to categorize BMI into obesity: >+2SD (equivalent to BMI 30 kg/m^2 at 19 years); overweight: +1SD to +2SD (equivalent to BMI 25 to 30 kg/m^2 at 19 years); thinness: -2SD to -3SD; and severe thinness: <-3SD [16]. MUAC was measured using a Shakir tape at the midpoint between the acromion process and the olecranon process on the left arm. The measurement was recorded to the nearest 0.1 cm. Mid-thigh circumference was measured at the midpoint between the inguinal crease and the proximal border of the patella on the left thigh using a flexible, non-stretchable tape [15].

Statistical Analysis

The collected data were entered into Microsoft Excel and analyzed using SPSS version 22. Continuous variables were expressed as means with standard deviation (SD), and categorical variables were represented as percentages. To find the association, the chi-square test or Fisher's exact test was used, and an unpaired t-test was used to find the differences in the anthropometric values by gender, with a p-value of less than 0.05 considered statistically significant. A matrix scatter plot was constructed to assess the relationship between BMI, age, and other anthropometric variables. Color codes represent different age categories, and the regression lines indicate direction and strength of association. Pearson's correlation coefficients quantified associations between BMI and alternative anthropometric measures. ROC curve analysis assessed the ability of MUAC and MTC to discriminate overweight and obesity, defined using WHO BMI-for-age Z-score thresholds. Optimal cut-off values were determined using the Youden Index (J = Sensitivity + Specificity − 1), with the highest J statistic indicating the best discriminatory threshold.[17] Area Under the Curve (AUC) values were computed to assess overall diagnostic accuracy.

RESULTS

A total of 532 students were included in the study, of which 274 (51.5%) were females and 258 (48.5%) were males. The mean age of the participants among females was 8.9 ± 2.1, and males were 9.1 ± 1.9 years. Table 1 compares the anthropometric characteristics between female and male participants. The mean BMI was significantly higher in females (18.6 ± 2.6) compared to males (18.1 ± 2.4) (p = 0.027). Similarly, the mid-thigh circumference of females was higher (34.5.6 ± 5.7 cm) compared to males (33.4 ± 5.5 cm) with a significant p value of 0.027. There was no significant difference found in the MUAC among female and male school students (females: 22.3 ± 3.4 cm; males: 21.8 ± 3.5 cm, p value-0.120). The prevalence of overweight was 21.9% among females and 14% among males. The prevalence of obesity was 14.2% among females and 9.3% among males (Table-2).

Table 3 and Figure 1 present the correlation between MUAC, mid-thigh circumference, and BMI among male and female school children. For MUAC and BMI, a strong positive correlation was observed in both genders, with males showing a higher r value (0.875) compared to females (0.864). Whereas, in mid-thigh circumference, females (r=0.825) demonstrated a very strong positive correlation with BMI than male (r=0.791) school children.

Screening Accuracy of Anthropometric Measures. MUAC—Mid-Upper Arm Circumference; MTC-Mid-Thigh Circumference; AUC – Area Under the Curve. Cut-off values for male and female children were determined using the Youden Index [17] Table 4, Figure 3, and Figure 4 show the diagnostic performance of mid-upper arm circumference (MUAC) and mid-thigh circumference (MTC) for identifying overweight and obesity, using BMI-for-age Z-scores as the reference standard, stratified by sex. ROC analysis demonstrated that both MUAC and MTC had excellent discriminatory ability for identifying obesity in children, with area under the curve (AUC) values ranging from 0.945 to 0.994 across sexes. MUAC showed strong performance among males for obesity (AUC = 0.994), with an optimal cut-off of 24.55 cm, achieving 100% sensitivity and 91.9% specificity (Youden Index = 0.919), while in females, AUC for MUAC was 0.945 with a specificity of (84.7%) at a cut-off of 22.35 cm. MTC demonstrated excellent accuracy for obesity in both sexes, with optimal cut-offs of 36.10 cm in females (AUC = 0.971; sensitivity = 100%, specificity = 86.6%) and 37.75 cm in males (AUC = 0.984; sensitivity = 100%, specificity = 91.5%). MTC has a good ability to discriminate between overweight and obesity in both genders (AUC for females: 0.876 and males: 0.897), compared to MUAC, which has lower specificity despite uniformly high sensitivity, indicating a greater overlap between the normal and overweight categories.

Table-1: Mean differences between genders in the Anthropometric measures of the study participants (n=532)

Characteristics		Female (n=274)	Male (n=258)	Test statistics	p-value#
Height (cm)	**Mean ± SD**	131.8 ±12.5	133.1±10.8	t=1.406	**0.160**
Weight (Kg)	**Mean ± SD**	32.9±8.5	32.4±7.9	t=-0.655	**0.513**
Mid-Upper Arm Circumference (cm)[15]	**Mean ± SD**	22.3 ± 3.4	21.8± 3.5	t=-1.556	**0.120**
Mid-thigh Circumference (cm)[15]	**Mean ± SD**	34.5 ± 5.6	33.4 ± 5.5	t=-2.224	**0.027***
Body Mass Index (cm) [15]	**Mean ± SD**	18.6 ± 2.6	18.1 ± 2.4	t=-2.901	**0.004***

*#Unpaired t-test; SD- Standard Deviation; *Significance: p < 0.05 -statistically significant.*

Table 2. Distribution of BMI-for-age categories by gender

Characteristics		Female (n=274) N (%)	Male (n=258) N (%)	Test statistics	p-value#
Classification of Body Mass Index as per WHO BMI for age (%)[16]	Severe Thinness (>-3SD)	7 (2.6)	11 (4.3)	$\chi^2 = 11.9$	**0.018***
	Thinness (-2SD to -3SD)	7 (2.6)	12 (4.7)		
	Normal (-2SD to +1SD)	161 (58.8)	175 (67.8)		
	Overweight (+1SD to +2SD)	60 (21.9)	36 (14)		
	Obese (>+2SD)	39 (14.2)	24 (9.3)		

*# Chi-Square Test; SD- Standard Deviation; *Significance: p < 0.05-statistically significant.*

Table-3: Pearson correlation coefficients between BMI and anthropometric measures

Measure	Females (r)	Males (r)	p-value
MUAC vs BMI	0.864	0.875	**<0.001**
MTC vs BMI	0.825	0.791	**<0.001**

[(Correlation Between BMI and Alternative Anthropometric Measures. Note: Each cell represents a pairwise scatter plot with fitted regression lines. Blue plots denote male children, and red plots denote female children. Correlation coefficients were computed using Pearson's r ($p < 0.05$ considered significant)]

Table 4: ROC analysis showing the diagnostic performance of mid-upper arm circumference (MUAC) and mid-thigh circumference (MTC) for identifying overweight and obesity, using BMI-for-age Z-scores as the reference standard, stratified by gender

Measure	Sex	Outcome	AUC	Optimal cut-off (cm)	Youden Index value	Sensitivity (%)	Specificity (%)
MUAC	Female	Obesity	0.945	22.35	0.647	100	84.7
		Overweight	0781	18.95	0.201	100	20.1
	Male	Obesity	0.994	24.55	0.919	100	91.9
		Overweight	0.807	21.75	0.649	100	64.9
MTC	Female	Obesity	0.971	36.10	0.716	100	86.6
		Overweight	0.876	32.45	0.481	100	78.1
	Male	Obesity	0.984	37.75	0.915	100	91.5
		Overweight	0.897	30.65	0.347	100	74.7

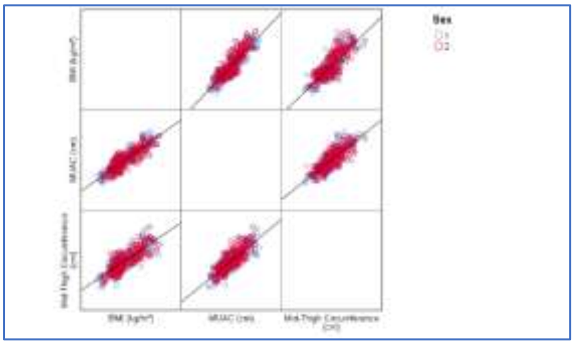

Figure 1: Matrix scatter plot showing correlation between MUAC, Mid-Thigh Circumference, and BMI among male and female children.

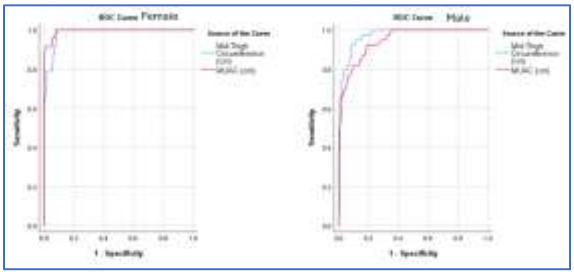

Figure-2: Receiver Operating Characteristic Curves of Mid-Upper Arm Circumference and Mid-Thigh Circumference for Detection of Obesity in Male and Female School Children

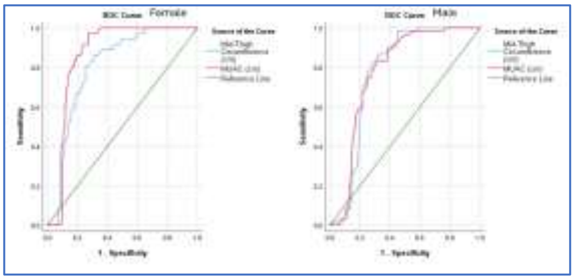

Figure 3: Receiver Operating Characteristic Curves of Mid-Upper Arm Circumference and Mid-Thigh Circumference for Detection of Overweight in Male and Female School Children

DISCUSSION

The present study was conducted to assess the validity of the MUAC and MTC for overweight and obesity in children aged 6-12 in Tamil Nadu using BMI for age Z Scores as the reference standard. In the present study, we found that female students had significantly higher mean MUAC (22.3 ± 3.4 cm), MTC (34.5±5.6), and BMI (18.6 ± 2.6) than males (MUAC: 21.8 ± 3.5 cm, MTC: 33.4±5.5, and BMI: 18.1 ± 2.4; p = 0.120, p=0.027 and p = 0.004, respectively). These findings align with those of Kadhilkar AV et al., Chang E et al., and Craig E et al., who reported that hormonal and physiological factors predispose to greater adiposity, thereby elevating BMI and MTC values among preadolescents.[10.18,19] Moreover, Reidder CM et al. and Blaak E et al., highlighted that sex-specific patterns of fat deposition, influenced by growth phases, explain the heightened anthropometric values observed in females during this developmental stage.[8,20] Also, we found no statistically significant gender differences for MUAC. The lack of a significant sex difference in MUAC suggests that upper-arm fat and muscle mass may develop more proportionately in this age group, whereas thigh circumference appears more sensitive to sex-related differences in body composition.

Childhood obesity and overweight pose a major challenge in India. The prevalence of obesity in the current study was significantly higher among females (14.2%) compared to males (9.3%), while the prevalence of overweight was 21.9% for females and 14% for males. These observations were similar to the findings from Ranjani et al., Mahajan PB et al., Jagadesan S., Kumar S et al., Mehadra et al., Gupta et al., and Laxmaiah A et al.,[4,5,21-25] These studies emphasized similar gender-specific trends in childhood obesity prevalence across India. However, studies conducted by Gautam et al., Vidya C et al., and Singh et al., reported male preponderance for obesity.[6,7,26] These variations in the gender prevalence suggest that gender-related differences in dietary habits, physical activity, and cultural constraints contributed to observed differences in India. On assessing the correlation of MUAC and MTC with the BMI, we found positive correlations in both genders. The present study demonstrated MUAC has a positive correlation with BMI, with an r-value of 0.864 for females and 0.875 for males. This shows that the correlation between MUAC and BMI was stronger in males than in females. These results are consistent with the studies by Khadilkar et al., Lu Q et al., Rerksuppaphol et al., Diwakar KK et al., and Craig E et al.[10,11,13,14,19] The present study also examined the correlation between MTC and BMI. We found that MTC showed a strong positive correlation with the BMI. MTC showed slightly stronger for females (r = 0.825) compared to males (r = 0.791). These variations highlight the differential utility of each parameter in capturing gender-specific body composition trends.

In the present study, MUAC demonstrated excellent discriminatory accuracy for identifying obesity in both sexes, with AUC values of 0.945 in females and 0.994 in males, and optimal cut-off values of 22.35 cm and 24.55 cm, respectively, each achieving 100% sensitivity with high specificity (84.7% in females and 91.9% in males). These findings are consistent with previous studies by Mahajan et al., Rerksuppaphol et al., Diwakar et al., and Chaput JP et al., which similarly reported MUAC cut-offs with high discriminative accuracy for identifying overweight and obese children, ranging from 20.2 to 25.4 cm in males and 19.8 to 25.4 cm in females, with reported sensitivities and specificities ranging from 83% to 97% and AUC values consistently exceeding 0.90 in both genders.[5,13,14,27] In the present analysis, MUAC showed moderate accuracy for identifying overweight, particularly in females (AUC 0.781, specificity 20.1%), while performance was comparatively better in males (AUC 0.807, specificity 64.9%). These incremental MUAC thresholds align with the natural progression of growth and development in children and reflect age- and sex-sensitive adiposity patterns, supporting MUAC as a robust screening tool for obesity rather than early overweight.

Mid-thigh circumference exhibited consistently high diagnostic accuracy for both obesity and overweight across genders. For obesity, MTC demonstrated excellent performance with AUC values of 0.971 in females (cut-off 36.10 cm) and 0.984 in males (cut-off 37.75 cm), achieving 100% sensitivity and high specificity (>86% in both sexes). Unlike MUAC, MTC retained good discriminatory ability for overweight, particularly among females (AUC 0.876, specificity 78.1%) and males (AUC 0.897, specificity 74.7%), suggesting greater sensitivity to peripheral fat distribution during early excess weight gain. Our study was consistent with the study conducted by Diwakar KK et al.[14] The observed consistency may be attributed to the fact that thigh circumference reflects subcutaneous and peripheral fat deposition, which increases earlier and more proportionately with excess energy storage during childhood and adolescence compared to central measures. Additionally, MTC is less influenced by short-term nutritional fluctuations and muscle mass variability, making it a stable anthropometric proxy for adiposity across age and sex groups. Overall, the ROC analysis from the present study reinforces that MUAC and MTC are reliable predictors of obesity in adolescents, with MUAC demonstrating higher predictive utility in females and MTC showing superior performance both in females and males. Collectively, these low-cost, non-invasive anthropometric indicators offer practical advantages for early identification of overweight and obesity in school and community settings, particularly in resource-limited environments, and support the adoption of gender-specific and measure-specific screening strategies within public health programs.

This study demonstrates the practical utility of multiple low-cost and non-invasive anthropometric indicators-MUAC and MTC-for early identification of overweight and obesity in school settings where resources are limited. The analysis provides useful insights into how predictive performance varies by age and gender, offering evidence that may support more tailored screening strategies in public health programs. However, several limitations should be acknowledged. The study was conducted in a single school, which may introduce cluster-related bias and restrict the generalizability of findings to wider populations. Additionally, the reference used to determine weight-status classification was BMI-for-age Z-scores, which cannot distinguish fat mass from muscle mass. As a result, the screening tools evaluated here were compared against a proxy rather than a direct measure of adiposity, which may lead to some degree of misclassification. Validation of these simple screening indicators in diverse settings and against more robust adiposity measures such as skinfolds or DEXA would strengthen future evidence.

CONCLUSION

This study demonstrates that mid-upper arm circumference (MUAC) and mid-thigh circumference (MTC) are accurate, low-cost screening tools for identifying obesity among adolescents, with AUC values exceeding 0.90 and perfect sensitivity across genders. MUAC showed stronger predictive ability for obesity, particularly in females, while MTC demonstrated better discrimination for both obesity and overweight in both genders. The observed gender-specific cut-offs underscore the need for tailored screening thresholds rather than uniform criteria. These simple, non-invasive measures may complement BMI in large-scale screening programs, particularly in resource-limited settings. Further research, including longitudinal designs and validation in diverse populations, is needed to highlight the discriminating power of the anthropometric indices.

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