Rwanda Medical Journal RMJ

ORIGINAL ARTICLE Open Access

Evaluation of arm circumference measurement as an alternative screening tool for determining moderate and severe thinness

Authors: M. Nwankwo[1,*]; B. Danborno[2]; S. A. Musa[2]; S. A. Akuyam[3]

Affiliations: [1]Department of Human Anatomy, College of Medicine, Federal University Lafia, Nigeria; [2]Department of Human Anatomy, College of Medical Sciences, Ahmadu Bello University Zaria, Nigeria; [3]Department of Chemical Pathology, College of Medical Sciences, Ahmadu Bello University Teaching Hospital, Zaria, Nigeria

ABSTRACT

INTRODUCTION: Mid-upper arm circumference (MUAC) is a simple, rapid, objective, and cheap method for field assessment of nutritional status. The goals of the present study were to generate appropriate MUAC cut-off scores for thinness and severe thinness and compare the diagnostic accuracy of MUAC.

METHODS: A cross-sectional study was conducted capturing sociodemographic and anthropometric measurements of children and adolescents (3,414 boys; 3,575 girls) aged 5-19 years randomly collected from two local government areas of Nasarawa State. The WHO (2007) Macro was used to generate gold standard cut-off points for BAZ <-2 and <-3, whereas receiver-operating characteristic curves were used to generate corresponding MUAC cut-offs for the stated BAZ values.

RESULTS: BMI and mean MUAC correlation were positive (r= 0.63, P <0.001 for boys; r= 0.68, P <0.001 for girls). The cut-off values of MUAC to detect moderate thinness among boys and girls aged 5-9, 10-15, and 16-19 years are respectively ≤16.7 cm, ≤19.8 cm, 24.5 cm and ≤17.8 cm, ≤20.8 cm, ≤23.0 cm.

CONCLUSION: The present study provides age- and sex-specific MUAC cutoffs for screening moderate/severe thinness in children and adolescents for use during emergency or resource-constraint settings.

Keywords: Mid-upper arm circumference, thinness, BMI, malnutrition, Nigeria

INTRODUCTION

Anthropometric measurements are important indicators of the health and nutritional status of children and adolescents and are consistently recommended by the World Health Organization [WHO] [1]. In Nigeria, anthropometric indicators are perhaps the most commonly used tools for assessing nutritional status, physical growth, and development of children and adolescents. Nutritional status can serve as an indicator of the prevailing socioeconomic climate of a population, especially in emerging economies [2-5], and as an index of physical growth and development [6]. Anthropometric indicators may be generated from a specific study, from national reference or based

***Corresponding author:** M. Nwankwo, E-mail: nmonday65@gmail.com, Tel: +2348065712691, Department of Human Anatomy, College of Medicine, Federal University Lafia, Nigeria;; **Potential Conflicts of Interest (CoI):** All authors: no potential conflicts of interest disclosed; **Funding:** All authors: No funding was sought for this study; **Academic Integrity.** All authors confirm that they have made substantial academic contributions to this manuscript as defined by the ICMJE; **Ethics of human subject participation:** The study was approved by the local Institutional Review Board. Informed consent was sought and gained where applicable; **Originality:** All authors: this manuscript is original has not been published elsewhere; **Review:** This manuscript was peer-reviewed by three reviewers in a double-blind review process; **Type-editor:** Peter (USA).
Received: 28th April 2024; **Initial decision given:** 14th July 2024; **Revised manuscript received:** 25th November 2024; **Accepted:** 11th January 2025.
 Publisher: Rwanda Biomedical Centre (RBC)/Rwanda Health Communication Center, P. O. Box 4586, Kigali. ISSN: 2079-097X (print); 2410-8626 (online)

Citation for this article: M. Nwankwo; B. Danborno; S. A. Musa, et al. Evaluation of arm circumference measurement as an alternative screening tool for determining moderate and severe thinness. Rwanda Medical Journal, Vol. 82, no.1, p. 12-22, 2025. https://dx.doi.org/10.4314/rmj.v82i1.2

on international reference. Body mass index [BMI], the most widely used indicator of nutritional status and distribution of adiposity [7] in the body, is measured as body weight [kg]/height [m2]. Because BMI is easily measured, inexpensive, non-invasive, and applicable to population studies, it has gained global acceptability [7-9]. The WHO prescription for classifying thinness and severe thinness in children and adolescents are respectively BMI-for-age z-score (BAZ) <-2 and <-3 [10]. Previous studies have linked low BMI to increased risk of morbidity and mortality [11-15]. Although procurement of weighing scale, stadiometer, and weight and height measurement is relatively easy, maintenance and calibration before use are necessary. Nevertheless, factors such as computation, resource constraints, bedridden patients, conflicts, and famine can make weight and height measurements difficult or impossible.

However, other surrogates for BMI as a conventional indicator of adiposity and nutritional status include mid-upper arm circumference (MUAC), calf circumference, triceps, and subscapular skinfold thicknesses [16]. MUAC is commonly used as an alternative index of nutritional status. It is a measure of the annulus of the upper arm midway between the olecranon and acromial process. Its operational advantages include applicability when a collection of weight and height measurements is arduous, such as in war-torn regions, internally displaced persons, famines, individuals who cannot stand unaided, and in bedridden patients. Other benefits of MUAC are that it is inexpensive, easy to measure, measuring tapes are portable and it has been verified to be a better predictor of childhood morbidity and mortality compared to weight- and height-based anthropometric indicators [17-19]. MUAC has also been shown to help monitor obesity, especially in developing countries [20-22]. Moreover, low MUAC appears to be a better predictor of mortality in HIV/AIDs patients [23-25] and geriatrics [26,27].

The WHO Integrated Management of Adolescent and Adult Illness (IMAI) Acute Care guidelines recommended that adolescents and adults can be classified as having severe undernutrition if they have a MUAC <160 mm or MUAC 161 – 185 mm plus one of the following: pitting edema up to the knees on both limbs or cannot stand or having sunken eyes. There are still controversies regarding using a single MUAC cut-off score in the general population and even among ethnic groups within the same country. For instance, an earlier study in Nigeria reported an optimal cut-off value of 23 cm in the north, whereas a cut-off value of 24 cm was recommended as appropriate in the south [28]. Despite the inconsistencies in cut-off points for use worldwide, there is growing consensus from recent studies over the use of MUAC to evaluate the nutritional status of adults, especially in resource-constrained environments [29-31]. Thus, given its application convenience and less resource-demanding, MUAC could serve as an ideal proxy tool for assessing thinness and severe thinness among Nigerians. Against this backdrop, the goals of the present study were to (i) generate appropriate MUAC cut-off scores equivalent to BAZ cut-off values for thinness and severe thinness, and (ii) compare the diagnostic accuracy of MUAC relative to BAZ of schoolchildren adolescents from Nasarawa State Nigeria.

METHODS

Study population

The present cross-sectional study included 6,989 participants (3,414 boys; 3,575 girls) aged 5 – 19 years. The study sample was collected using multistage sampling with three stages. The first stage involved a random sample of local governments (LGs) in Nasarawa State, with the probability of being selected proportionate to the LG population. In the second stage, a random sample of schools (primary and secondary) nested within the selected LG was obtained. At the final stage, participants were selected at random within each school. The study was conducted between 2018 to 2019. The purpose of the study was communicated to teachers of the selected schools. Only schools which authorities gave signed informed consent were included in the study. In addition to permission obtained from authorities of participating schools, parents (in the case of children below 18 years old) gave their informed consent to enlist their children, whereas, subjects 18 and 19 years gave their informed consent to participate in the study. Inclusion criteria are schoolchildren and adolescents aged 5 – 19 years attending day school, present on the day of data collection, and who submit signed informed consent from their parents/guardians. Schoolchildren with acute or chronic conditions or on medication at the time of the study were not included. The Ahmadu Bello University Ethics

Committee approved the study protocol on the Use of Human Subjects for Research (approval No: ABUCUHSR/2018/004). The study was carried out per the guidelines in the 1964 Declaration of Helsinki (as amended) with close attention to the provisions in the Protection of Personal Information Act (no. 25326).

Anthropometric measurements

Anthropometric measurements, including height, weight, and MUAC, were obtained from each participant using the standardized protocols of the International Society for the Advancement of Kinanthropometry (ISAK)[32]. Weight and height were measured to the nearest 0.1 kg and 0.1 cm, respectively. MUAC was measured in centimeters using non-extensible tape midway between the olecranon and acromial process of the left arm in a relaxed position. Trained research assistants took measurements along with one of the authors, MN, who provided training to the research assistants. Intra- and inter-observer errors were maintained below 5%, ensuring measurement standardization [32].

Statistical analysis

Data were analyzed using Statistical Product and Service Solutions (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) and MedCalc Statistical Software version 22.017 (MedCalc Software bvba, Ostend, Belgium; https://www.medcalc.org; 2020). Z-scores were generated using the WHO 2007 SPSS macros [33]. The application generated and saved results (as new variables) of subjects categorized as thinness (BAZ <-2) and severe thinness (BAZ <-3) and also flagged outlying values. The flagged values were excluded from the analyses. Next, diagnostic accuracy of MUAC as a screening tool for thinness and severe thinness relative to BAZ was then evaluated using the receiver operating characteristic (ROC) curve. Consequently, sensitivity (SN), specificity (SP), positive predictive value (PPV) and negative predictive value were computed using the proportion of true negatives (TN), false negatives (FN), and true positive (TP), false positive (FP) using a 2 x 2 cross-tabulation coding table below:

SN indicates how likely subjects detected as being thin/severely thin using BAZ criteria are to be diagnosed as thin/severely thin using the MUAC cut-off value for thin/severely thin for that age and sex, whereas, SP indicates how likely subjects detected as not being thin/severely thin using BAZ are to be detected as not being thin/severely thin using MUAC cut-off value for thin/severely thin for their age and sex. SN = TP/(TP + FN) while SP = TN/(FP + TN). PPV is the proportion of thin/severely thin, which is detected as thin/severely thin, and NPV is the proportion of subjects who are not thin/severely thin and are detected as not thin/severely thin.

PPV = TP/(TP + FP), NPV = TN/(FN + TN). FN is the proportion of subjects who are thin/severely thin according to the BAZ criteria but are detected as not being thin/severely thin using the new MUAC cut-off value, that is FN/(TP + FN). FP, on the other hand, is the proportion of subjects who are not thin/severely thin but were detected as thin/severely thin using the new MUAC cut-off value, FP/(FP + TN). Cohen's Kappa was used to test the degree of agreement between the gold standard and MUAC cut-off values generated from the present study. For each sex and age, the predictive accuracy of each cut-off value was evaluated by determining the percentage misclassification of the new criteria against the gold standard. Statistical significance was set at P <0.05; all P values are two-tailed.

RESULTS

Accuracy of MUAC as indicator for thinness and severe thinness

The area under the curve was utilized to assess the diagnostic accuracies of MUAC in accurately detecting thinness. The trade-off between

Table 1: Thinness

Thinness based on generated MUAC cut-off value	Thinness based on BAZ		
	Yes	No	Total
Yes	TP	FP	TP + FP
No	FN	TN	FN + TN
Total	TP + FN	FP + TN	N

sensitivity and specificity is presented in the form of the ROC curve. Tables 1 and 2 summarized the sensitivity, specificity, predictive values, and likelihood ratios of MUAC as an indicator of thinness (BAZ < –2) and severe thinness (BAZ <–3) of participants using BMI as the gold standard screening test. The prime requirement of MUAC as a proxy screening tool for BMI is that it should correctly identify the majority of thin and severely thin cases. The false-positive rate assesses the proportion of individuals not identified as thin or severely thin using the gold standard (BMI) as the diagnostic tool who would be picked out as thin or severely thin (as the case may be) using MUAC as the screening tool. On the other hand, the false negative rate indicates the proportion of participants who were identified as thin or severely thin by the gold standard but were not picked out using MUAC as the screening tool.

The MUAC cut-off values for thinness in both sexes increase with age. The cut-off values of MUAC to detect thinness among boys aged 5 – 9, 10 – 15, and 16 – 19 years are respectively ≤16.7 cm (SN = 62%, SP = 63%), ≤19.5 cm (SN = 62%, SP = 71%) and 24.5 cm (SN = 81%, SP = 56%). Single-age cut-off points range between ≤15.0 cm (SN = 67%, SP = 73%) at age 5 years and ≤21.5 cm (SN = 75%, SP = 82%) at age 15 years. Regarding the area under the ROC, age 5 was found to be the best age, with the highest area under the ROC curve being 0.83 (95% CI 0.70, 0.91) for boys. Other ages with similar high AUC among boys are ages 13, 14, 10 and 16 – 19 years with AUC of 0.80 (95% CI 0.76, 0.85), 0.75 (95% CI 0.70, 0.80), 0.71 (95% CI 0.66, 0.76) and 0.75 (95% CI 0.71, 0.79) respectively (Table 1). The highest sensitivity (81%) was recorded at age 16 – 19, while the highest specificity (82%) was at age 15. The lowest sensitivity, 58% in boys, was at age 10, and age 6, had the lowest specificity. Furthermore, all the NPVs of MUAC in this study were more than the PPVs, suggesting that MUAC was suitable for excluding the population of individuals who were not thin from a population of thin individuals. Figure 1 (a) shows the corresponding ROC curves.

Still on Table 1, the optimal MUAC cut-off values for girls at ages 5 – 9 years, 10 – 15 years, and 16 – 19 years are respectively ≤17.8 cm (SN = 78%, SP = 41%), ≤20.8 cm (SN = 72%, SP = 64%) and ≤23.0 cm (SN = 90%, SP = 70%). Whereas, single-age cut-off points ranges between ≤15.5 cm (SN = 85%, SP = 46%) and ≤22.8 cm (SN = 80%, SP = 59%) respectively. The age range 16 – 19 years is the best age for detecting thinness among girls with an optimal AUC of 0.84 (95% CI 0.80, 0.87). MUAC was also found to be a good predictor of thinness at ages 13, 14, 15, and 12 years with AUC of 0.76 (95% CI 0.71, 0.80), 0.79 (95% CI 0.74, 0.83), 0.76 (95% CI 0.71, 0.81) and 0.57 (95% CI 0.52, 0.63) respectively. For girls, the cut–off points of MUAC with sensitivity ≥ 80% in predicting thinness were ≤ 15.5 cm, ≤22.8 cm, and ≤23.0 cm at ages 5, 15, and 16 – 19 years, respectively. The highest sensitivity (90%) was at age 16 – 19, whereas the highest specificity (80%) was at age 13. The lowest specificity (40%) is at age 8 years. The sex-wise comparison revealed that girls have higher MUAC cut-off points than their male counterparts except at age 6 years and 16 – 19 years. Figure 1 (b) shows the corresponding ROC curves.

MUAC performed optimally as an indicator of severe thinness among boys aged 15 years with the highest AUC of 0.89 (95% CI 0.84, 0.92) (Table 2). Single-age MUAC cut-off value for boys ranged between ≤15.0 cm (SN = 78%, SP = 67%) at 5 years to ≤21.5 cm (SN = 92%, SP = 74%) at 15 years. The cut-off values of MUAC at ages 5 – 9 years, 10 – 15 years and 16 – 19 years and their corresponding SN and SP are respectively ≤16.5 cm (SN = 61%, SP = 60%), ≤19.5 cm (SN = 69%, SP = 65%) and ≤24.5 cm (SN = 72%, SP = 63%). The highest sensitivity is 92% at age 15 years, whereas the highest specificity is 80% at age 13 years. The lowest sensitivity and specificity are 61% (at ages 10 years and ages 5 – 9 years) and 46% at age 7. Figure 2 (c) shows the corresponding ROC curves.

In girls, the cut-off value ranged from ≤15.5 cm (SN = 67%, SP = 72%) at age 5 years to ≤21.7 cm at age 15 years (SN = 81%, SP = 64%) (Table 2), respectively. The ROC curves for ages 5 – 8 years are not significantly different (P > 0.05) from 0.5, indicating MUAC's inability to distinguish between subjects with severe thinness from the normal group. The optimal cut-point values of MUAC with sensitivity ≥ 80% for predicting severe thinness were 16.0 cm, 21.7 cm, and 22.5 cm at ages 7, 14 – 15, and 16 – 19 years, respectively. The cut-off value at age 10 years had the highest specificity (88%), age 14 had the highest sensitivity (98%), while age of 10 years had the lowest significant sensitivity (36%) for detecting severe thinness

Table 1: Performance of various cut-off points of MUAC as a predictor of thinness (BAZ <-2 as gold diagnostic standard) for children and adolescents aged 5 – 19 years

Age (yrs.)	CP§	SN (%)	SP (%)	YI	LR	ROC AUC	PPV (%)	NPV (%)	FP (%)	FN (%)
Boys (n = 3,426)										
5	≤15.0	67 (41, 87)	73 (56, 86)	0.49	2.47	0.83 (0.70, 0.91)	55 (39, 69)	82 (70, 90)	45	18
6	≤16.0	75 (61, 85)	39 (30, 48)	0.13	1.21	0.58 (0.50, 0.65)	35 (30, 39)	78 (68, 85)	65	22
7	≤16.5	70 (59, 80)	45 (36, 54)	0.20	1.27	0.61 (0.54, 0.68)	46 (40, 51)	69 (60, 77)	54	31
8	≤16.5	59 (49, 69)	80 (73, 86)	0.40	2.99	0.71 (0.66, 0.77)	63 (55, 71)	78 (73, 82)	37	63
9	≤17.3	65 (56, 74)	66 (59, 73)	0.31	1.93	0.71 (0.66, 0.77)	57 (51, 63)	74 (68, 79)	43	57
10	≤18.0	58 (49, 67)	81 (75, 86)	0.39	3.10	0.71 (0.66, 0.76)	67 (59, 73)	75 (71, 79)	33	67
11	≤18.5	62 (52, 71)	71 (63, 78)	0.33	2.09	0.70 (0.64, 0.75)	59 (52, 66)	74 (68, 78)	41	59
12	≤19.5	65 (54, 74)	65 (58, 71)	0.30	1.84	0.66 (0.60. 0.71)	47 (41, 53)	79 (74, 84)	53	47
13	≤20.0	74 (64, 82)	70 (64, 76)	0.47	2.45	0.80 (0.76, 0.85)	51 (46, 57)	86 (82, 90)	49	51
14	≤21.5	80 (71, 87)	57 (50, 65)	0.37	1.87	0.75 (0.70, 0.80)	51 (46, 56)	84 (77, 89)	49	51
15	≤21.5	75 (65, 84)	82 (75, 87)	0.57	4.17	0.82 (0.77, 0.88)	66 (58, 73)	88 (83, 91)	34	66
5- 9	≤16.7	62 (56, 67)	63 (60, 67)	0.25	1.68	0.65 (0.62, 0.68)	45 (42, 48)	78 (75, 80)	55	22
10- 15	≤19.5	62 (58, 66)	71 (68, 73)	0.33	2.10	0.71 (0.68, 0.73)	53 (50, 56)	78 (76, 80)	47	53
16 – 19	≤24.5	81 (75, 87)	56 (50, 61)	0.37	1.84	0.75 (0.71, 0.79)	50 (47, 54)	84 (80, 88)	50	16
Girls (n = 3,482)										
5	≤15.5	85 (62, 97)	46 (34, 58)	0.34	1.57	0.69 (0.59, 0.79)	31 (25, 37)	91 (79, 97)	69	9
6	≤15.5	45 (30, 61)	73 (65, 80)	0.18	1.66	0.57 (0.50, 0.64)	33 (25, 43)	82 (77, 86)	67	18
7	≤16.0	77 (62, 89)	50 (42, 58)	0.27	1.55	0.65 (0.57, 0.71)	32 (27, 37)	88 (81, 93)	68	12
8	≤17.0	73 (61, 82)	40 (32, 49)	0.15	1.21	0.59 (0.52, 0.66)	39 (35, 44)	73 (64, 81)	61	27
9	≤17.8	69 (60, 77)	64 (57, 71)	0.33	1.93	0.69 (0.63, 0.75)	56 (50, 61)	76 (70, 81)	44	24
10	≤18.0	72 (64, 79)	56 (48, 63)	0.30	1.63	0.67 (0.61, 0.73)	56 (51, 60)	72 (66, 78)	44	28
11	≤18.5	68 (58, 77)	57 (50, 65)	0.27	1.60	0.63 (0.57, 0.69)	49 (43, 54)	75 (69, 81)	51	25
12	≤19.6	63 (51, 73)	55 (48, 61)	0.17	1.38	0.57 (0.52, 0.63)	32 (27, 37)	81 (76, 86)	68	19
13	≤19.8	61 (52, 69)	80 (74, 85)	0.40	3.00	0.76 (0.71, 0.80)	64 (57, 71)	77 (73, 81)	36	23
14	≤20.7	75 (66, 82)	73 (67, 79)	0.48	2.80	0.79 (0.74, 0.83)	63 (57, 68)	83 (78, 87)	37	17
15	≤22.8	80 (72, 87)	59 (51, 65)	0.38	1.92	0.76 (0.71, 0.81)	53 (49, 58)	83 (77, 88)	47	17
5- 9	≤17.8	78 (74, 83)	41 (37, 45)	0.19	1.33	0.61 (0.58, 0.64)	38 (36, 40)	80 (76, 83)	62	20
10- 15	≤20.8	72 (68, 64)	64 (61, 67)	0.36	1.99	0.74 (0.72, 0.76)	48 (45, 50)	83 (82, 85)	52	17
16 – 19	≤23.0	90 (82, 96)	70 (66, 75)	0.61	3.05	0.84 (0.80, 0.87)	40 (36, 44)	97 (95, 99)	60	3

CP cut-off point, SN sensitivity, SP specificity, YI Youden index, LR likelihood ratio, ROC receiver operating characteristics, AUC area under curve, PPV positive predictive value, NPV negative predictive value, FP false positive, FN false negative. 95% CIs in parentheses. Boldface represents a statistically significant difference in the ROC curve from 0.5. § Each cut-off point was chosen so that 95% of all malnourished children would be identified as such by the MUAC value.

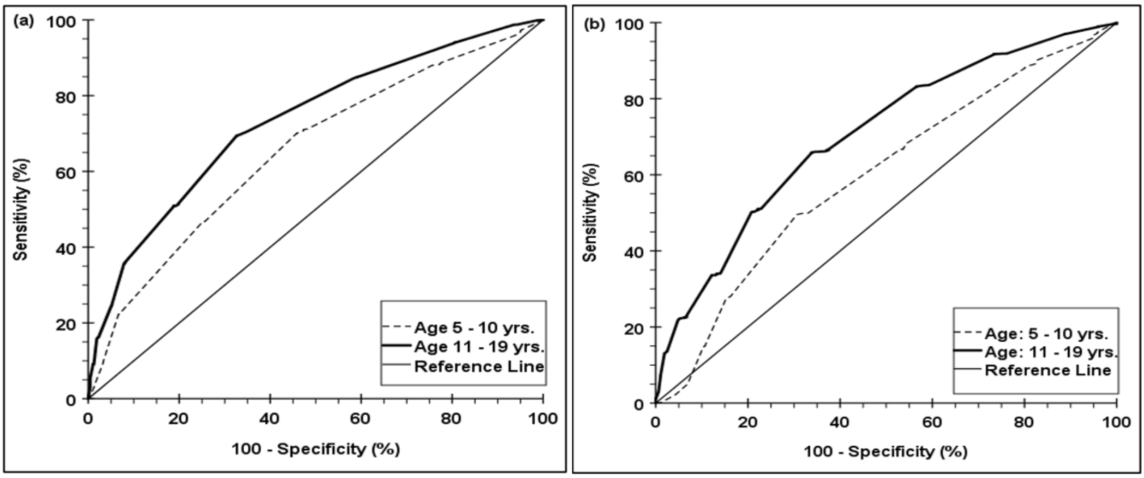

Figure 1: Ability of receiver operating characteristic curves of MUAC to detect thinness (BMI-for-age <-2) for children aged 5– 19 years.

MUAC was significantly better than chance as a diagnostic test for thinness in both boys (a) and girls (b). (a) Sensitivity = 54.13 (49.6, 58.6), specificity = 70.13 (67.1, 73.0), AUC = 0.654, P <0.001, associated criterion = 16.5 cm for boys aged 5 – 10 yrs. Sensitivity = 65.34 (61.8, 68.8), specificity = 60.90 (58.1, 63.7), AUC = 0.679, P <0.001, associated criterion = 20.7 cm for boys aged 11 – 19 yrs. (b) Sensitivity = 69.39 (65.0, 73.5), specificity = 49.50 (46.2, 52.8), AUC = 0.599, P <0.001, associated criterion = 17.8 cm for girls aged 5 – 10 yrs. Sensitivity = 76.55 (72.7, 80.1), specificity = 66.86 (64.4, 69.2), AUC = 0.775, P <0.001, associated criterion = 21.8 cm for girls aged 11 – 19 yrs.

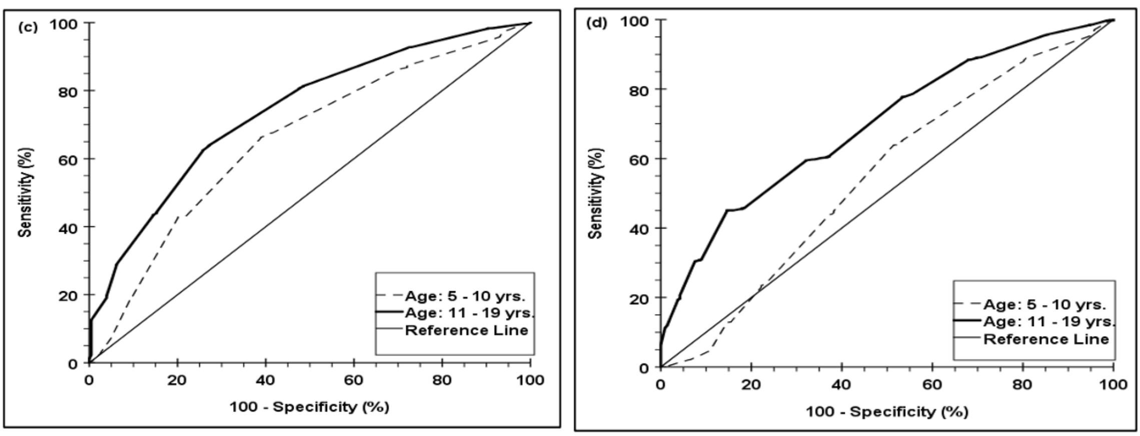

Figure 2: Ability of receiver operating characteristic curves of MUAC to detect severe thinness (BMI-for-age <-3) for children aged 5 – 10 and 11 – 19 years.

MUAC was significantly better than chance as a diagnostic test for severe thinness in both boys (c) and girls (d). (c) Sensitivity = 61.14 (54.5, 67.5), specificity = 66.31 (63.6, 69.0), AUC = 0.656 (0.63, 0.68), P <0.001, associated criterion = 16.5 cm for boys, 5 – 10 yrs. Sensitivity = 60.55 (55.0, 65.9), specificity = 71.45 (69.1, 73.6), AUC = 0.716 (0.70, 0.74), P <0.001, associated criterion = 19.5 cm for boys aged 11 – 19 yrs. Sensitivity = 48.58 (41.7, 55.5), specificity = 63.94 (61.1, 66.7), AUC = 0.549 (0.52, 0.58), P = 0.025, associated criterion = 16.7 cm for girls 5 – 10 yrs. Sensitivity = 84.79 (79.3, 89.3), specificity = 60.80 (58.5, 63.0), AUC = 0.778 (0.76, 0.80), P <0.001, associated criterion = 21.7 cm for girls aged 11 – 19 yrs.

in girls. The highest and lowest specificity values are 88% and 46%, respectively. While comparing sex-wise indicated that the optimal MUAC cut-off value for screening severe thinness was higher among girls at ages 5, 6, 11, 14 and 15 years than those of boys. Nevertheless, these differences may not be significant and were not tested in this study since they are not the focus of the study. The small variations suggest the possibility of having a single cut-off value that detects severe thinness for both sexes of these age groups. Figure 2 (d) is the corresponding ROC curves.

Table 2: Performance of various cut-off points of MUAC as an indicator of severe thinness (BAZ <-3 as gold diagnostic standard) for children and adolescents aged 5 – 19 years

Age (yrs.)	CP§	SN (%)	SP (%)	YI	LR	ROC AUC	PPV (%)	NPV (%)	FP (%)	FN (%)
Boys (n = 3,426)										
5	≤15.0	78 (40, 97)	67 (52, 81)	0.45	2.39	0.80 (0.67, 0.89)	32 (21, 45)	94 (82, 98)	68	6
6	≤15.0	67 (43, 85)	69 (61, 76)	0.36	2.15	0.66 (0.59, 0.73)	22 (16, 22)	94 (90, 97)	78	6
7	≤16.0	67 (51, 80)	46 (38, 54)	0.19	1.23	0.58 (0.51, 0.65)	26 (21, 31)	83 (76, 89)	74	17
8	≤16.0	62 (47, 75)	72 (66, 78)	0.34	2.23	0.66 (0.60, 0.72)	33 (27, 40)	90 (86, 93)	67	10
9	≤17.3	71 (58, 82)	60 (53, 67)	0.32	1.78	0.70 (0.64, 0.74)	32 (27, 37)	89 (84, 92)	68	11
10	≤18.0	61 (49, 73)	73 (67, 78)	0.34	2.28	0.66 (0.61, 0.71)	37 (31, 44)	88 (84, 91)	63	12
11	≤18.0	74 (60, 85)	67 (60, 74)	0.41	2.24	0.72 (0.66, 0.77)	36 (31, 43)	91 (86, 94)	64	9
12	≤18.5	60 (45, 74)	78 (72, 83)	0.38	2.72	0.68 (0.63, 0.74)	36 (29, 44)	91 (87, 93)	64	9
13	≤19.5	69 (55, 82)	80 (75, 85)	0.50	3.53	0.78 (0.73, 0.82)	37 (31, 45)	94 (91, 96)	63	6
14	≤20.5	75 (62, 86)	73 (67, 79)	0.49	2.82	0.83 (0.78, 0.88)	40 (34, 47)	93 (89, 95)	60	7
15	≤21.5	92 (79, 98)	74 (68, 80)	0.66	3.55	0.89 (0.84, 0.92)	39 (33, 45)	98 (95, 99)	61	2
5- 9	≤16.5	61 (53, 68)	60 (57, 64)	0.20	1.53	0.63 (0.60, 0.66)	26 (23, 28)	87 (85, 89)	74	13
10- 15	≤19.5	69 (64, 75)	65 (63, 68)	0.35	2.01	0.72 (0.70, 0.74)	30 (28, 32)	91 (89, 92)	70	9
16 – 19	≤24.5	72 (57, 84)	63 (59, 68)	0.35	1.96	0.71 (0.67, 0.75)	17 (14, 20)	96 (93, 97)	83	4
Girls (n = 3,482)										
5	≤15.5	67 (30, 93)	72 (61, 81)	0.38	2.35	0.72 (0.61, 0.81)	21 (13, 32)	95 (88, 98)	79	5
6	≤15.5	48 (26, 70)	74 (67, 80)	0.22	1.83	0.58 (0.51, 0.65)	19 (12, 28)	92 (88, 95)	81	8
7	≤16.0	91 (59, 100)	46 (38, 53)	0.37	1.68	0.59 (0.52, 0.66)	9 (8, 11)	99 (93, 100)	91	1
8	≤16.0	52 (33, 70)	63 (56, 70)	0.15	1.40	0.56 (0.49, 0.63)	20 (14, 26)	88 (84, 92)	80	12
9	≤16.0	56 (40, 71)	78 (72, 83)	0.33	2.49	0.67 (0.62, 0.73)	31 (24, 39)	91 (87, 93)	69	9
10	≤16.4	36 (24, 49)	88 (83, 92)	0.23	2.94	0.60 (0.55, 0.66)	40 (29, 51)	86 (83, 88)	60	14
11	≤18.2	65 (49, 79)	51 (44, 58)	0.18	1.33	0.54 (0.48, 0.60)	20 (16, 24)	89 (84, 92)	80	11
12	≤19.5	52 (31, 72)	50 (44, 55)	0.13	1.03	0.51 (0.46, 0.57)	8 (5, 11)	93 (89, 95)	92	7
13	≤19.5	67 (52, 81)	70 (65, 75)	0.37	2.25	0.74 (0.69, 0.79)	25 (20, 30)	94 (91, 96)	75	6
14	≤21.7	98 (88, 100)	46 (41, 53)	0.44	1.83	0.77 (0.72, 0.81)	23 (21, 25)	99 (95, 100)	77	1
15	≤21.7	81 (66, 91)	64 (58, 69)	0.44	2.22	0.74 (0.69, 0.79)	25 (21, 29)	96 (92, 98)	75	4
5- 9	≤16.7	67 (58, 75)	52 (49, 56)	0.19	1.41	0.59 (0.56, 0.62)	16 (14, 18)	92 (90, 94)	84	8
10- 15	≤18.7	49 (42, 55)	72 (70, 75)	0.21	1.77	0.64 (0.61, 0.66)	22 (19, 24)	90 (89, 91)	78	10
16 – 19	≤22.5	89 (77, 97)	70 (66, 74)	0.60	3.00	0.83 (0.79, 0.85)	20 (18, 23)	99 (97, 99)	80	1

CP cut-off point, SN sensitivity, SP specificity, YI Youden index, LR likelihood ratio, ROC receiver operating characteristics, AUC area under curve, PPV positive predictive value, NPV negative predictive value, FP false positive, FN false negative. 95% CIs in parentheses. Boldface represents a statistically significant difference in the ROC curve from 0.5. § Each cut-off point was chosen so that 95% of all malnourished children would be identified as such by the MUAC value.

DISCUSSION

The present study showed that MUAC is an alternative screening tool to identify moderate and severe thinness in children and adolescents aged 5 – 19 years, generally assessed by BMI. MUAC showed a significant association with mean total BMI for each sex and across ages (except for girls at age 5 years), suggesting that it can be used to identify individuals at greater risk of thinness and severe thinness. Relevant studies that assessed the diagnostic performance of MUAC to detect thinness compared to BAZ score among Nigerian children and adolescents are scant. The idea to establish MUAC cut-off points in the general population of adolescents' dates back to the late 1990s when the need to quickly diagnose and prioritize large numbers of severely malnourished persons for special nutritional intervention during emergencies, such as famine, war or disease outbreaks [34-36]. Albeit low BMI was recognized as a valuable screening tool for detecting severe malnutrition and predicting increased risk of morbidity and mortality, its use has been found to be challenging in settings where time and resources are limited. BMI measurement also requires arithmetic literacy; calibration and maintenance of measuring instruments are also necessary.

The AUC results showed that MUAC has a good diagnostic performance compared to BAZ in detecting adolescents who are moderately or severely thin. Our study results are in keeping with similar studies designed to assess whether MUAC can replace BMI for assessing malnutrition [37- 39]. These studies also reported a significant linear association between MUAC and BMI. One of these studies reported high sensitivity (97%) and specificity (71%) of MUAC in screening malnourishment among adolescents (10-19 years) (37). A study by De Kankana [38] showed that adolescent girls have a mean MUAC of 21.7 cm and that BMI and MUAC are significantly correlated. A study conducted on Indian adolescents by Gupta and his associates showed that the strength of association between BAZ <-2 and MUAC was significant. They then concluded that MUAC can be used as an alternative tool to measure thinness. In addition, they also showed the optimal MUAC cut-off point to be <18.5 cm and <16.5 cm for BAZ <-2 and BAZ <-3, respectively. However, a study done by Jeyakumar and colleagues reported that MUAC has higher specificity but low sensitivity [39].

Although previous studies have shown strong and significant associations between low MUAC (<23 cm or ≤23 cm) and low BMI (<18.5 kg/m2) [40-42], more studies are needed to determine whether different standardized cut-offs should be recommended based on subpopulation or based on contexts (famine relief/humanitarian assistance vs disease treatment programs e.g. HIV), for instance, some studies considered both men and women [34,36,43]; some only girls [40-42,44,45], or only boys [40].

The present study found that the optimal MUAC cut-off point to detect thinness in boys children, young adolescents, and late adolescents aged 5 – 9, 10 – 15, and 16 - 19 years are respectively 16.7 cm, 19.5 cm, and 24.5 cm whereas the cut-off points to detect severe thinness are respectively 16.5 cm, 19.5 cm and 24.5 cm for the same age groups. In girls, the MUAC cut-off point to identify thinness for children and adolescents aged 5 – 9, 10 – 15, and 16 – 19 years are 17.8 cm, 20.8 cm, and 23.0 cm, respectively. The optimal MUAC cut-off points to identify severe thinness among girls of the same age range are 16.7 cm, 18.7 cm, and 22.5 cm, respectively.

Furthermore, the specificity of the MUAC cut-off (≤16.5 cm) among boys 5 – 10 years for BAZ < -2 (70.1%) was higher than the specificity of the MUAC cut-off (≤16.5 cm) for BAZ < -3 (66.3%), indicating that MUAC can be more specific in diagnosing thinness than severe thinness in malnourished population. In contrast, the specificity of the MUAC cut-off (≤20.7 cm) for boys aged 11 – 19 years for BAZ < -2 (60.9%) was lower than the specificity of the MUAC cut-off (≤ 19.5 cm) for BAZ <-3 (71.5%), signifying that MUAC can be more specific in detecting thinness among severely malnourished adolescent boys. In general, MUAC is relatively more specific than sensitive in identifying thinness among malnourished boys.

In girls, 5 – 10 years, the sensitivity of the MUAC cut-off (17.8 cm) for BAZ <-2 (69.4%) is higher than the sensitivity of MUAC cut-off (16.7 cm) for BAZ < -3 (48.6%), signifying that MUAC is more sensitive in detecting thinness than severe thinness in malnourished girl population. Conversely, the sensitivity of the MUAC cut-off (21.7 cm) for BAZ <-3 (84.8%) is higher than the sensitivity of the MUAC cut-off (21.8 cm) for BAZ < -2 (76.6%), indicating that MUAC is more sensitive for diagnosing of thinness in severely malnourished girl population. The results of sensitivity and specificity of the present study were slightly lower than that reported by Gupta and associates, who found that for BAZ <-2, the sensitivity and specificity of MUAC cut-off point <18.5 cm were respectively 73 and 79% for diagnosing thinness in adolescent girls age 10 – 19 years. Higher specificity (97.3%) was reported in the same study for BAZ <-3 as the diagnostic criterion for a MUAC cut-off point of <16 cm. However, the specificity and sensitivity in our study for girls 11 – 19 years were higher than that reported by De (2016) for girls 10 – 19 years old, in which a sensitivity of 53.4% and specificity of 79.9% were reported. Another study done by Jeyakumar and colleagues showed that MUAC has lower sensitivity (28.5%) but higher specificity (96.5%) [46]. From the foregoing, results from previous studies indicate that MUAC has higher specificity but lower sensitivity in diagnosing thinness for BAZ <-2 whereas MUAC has higher sensitivity but lower specificity for detecting severe thinness for BAZ < -3. This is corroborated by the present study. The present study also demonstrates that for children and adolescents of both sexes and across all ages, NPV was consistently higher than PPV for BAZ < -2 and BAZ <-3 as the gold standards, signifying that MUAC cut-off points were able to accurately exclude individuals without thinness based on BAZ.

As mentioned earlier, a paucity of studies assessed the diagnostic performance of MUAC compared to BAZ in identifying children and adolescents with thinness in Nigeria. More studies are necessary in other LGAs of Nasarawa State and other parts of Nigeria to add to the growing body of literature in search of a standard MUAC cut-off for malnourishment among children, adolescents, pregnant women, and populations in crisis. There is a need for various stakeholders in Nigeria to decide whether or not to establish a low MUAC cut-off point as a proxy for BMI indicators and/or to establish optimal MUAC cut-off points for predicting outcomes of other health conditions.

The present study has its strengths and limitations. The strength of the study is that anthropometric measurements were carried out using a standardized measurement protocol, and various quality control measures were taken to ensure that the data are of high quality. Another strength of the present study is the use of a relatively large sample size and the generation of both grouped cut-offs and single age- and sex-specific cut-off points. The grouped cut-offs can be handy in cases where the child's specific age is not known. Although the samples were drawn from rural and urban settings, the study couldn't establish a single MUAC cut-off point with a generic application for identifying malnourished children and adolescents. The study couldn't establish what level of sensitivity and specificity are recommended for a particular MUAC cut-off point. The fact that samples were collected from only two out of the 13 LGAs of the State is another limiting factor to the study that limits the generalizability of the results. The results cannot be used as national year-wise MUAC cut-off points for requisite interventions during emergency situations.

CONCLUSION

In conclusion, the present study reveals that MUAC has relatively similar accuracy to BAZ. Consequently, MUAC could be used as an alternative tool for screening and surveillance of moderate and severe thinness among children and adolescents aged 5 – 19 years. We recommend that future studies determine whether or not different standardized cut-off points should be recommended to various subpopulations (for instance, children vs. adolescents, adolescents vs. adults, men vs. women).

REFERENCES

1. World Health Organization Physical Status: The Use and Interpretation of Anthropometry. Report of a WHO Expert Committee. WHO Technical Report Series no. 854 1995, Geneva: WHO.
2. Ferro-Luzzi, A.; Sette, S.; Franklin, M. et al. A simplified approach of assessing adult chronic energy deficiency. Eur J Clin Nutr 1992, 46, 173–186.
3. Shetty, P.S.; James, W.P.T. Body Mass Index: A Measure of Chronic Energy Deficiency in Adults. Food and Nutrition Paper no. 56. 1994, Rome: FAO.
4. Nube, M.; Asenso-Okyere, W.K.; van den Bloom, G.J.M. Body mass index as an indicator of standard of living in developing countries. Eur J Clin Nutr

1998, 77, 1186–1191.
5. Khongsdier, R. Body mass index and morbidity in adult males of the War Khasi in Northeast India. Eur J Clin Nutr 2002, 56, 484–489.
6. WHO Physical status: the use and interpretation on anthropometry. Report of a WHO Expert Committee: World Health Organization 1995, Geneva.
7. Cole, T.J.; Bellizzi, M.C.; Flegal, K.M.; Dietz, W.H. Establishing a standard definition for child overweight and obesity worldwide: international survey. BMJ 2000, 320:1240–3.
8. World Health Organization 2007 Growth reference 5–19 years: BMI-for-age (5–19 years). http://www.who.int/growthref/who2007_bmi_for_age/en/ (Accessed January, 2024).
9. Woodruff, B.A.; Duffield, A. Anthropometric assessment of nutritional status in adolescent populations in humanitarian emergencies. Eur J Clin Nutr 2002, 56:1108e18.
10. World Health Organization 2007 Growth reference 5–19 years: BMI-for-age (5–19 years). http://www.who.int/growthref/who2007_bmi_for_age/en/ (accessed January, 2024).
11. Aune, D.; Sen, A.; Prasad, M. BMI and all-cause mortality: systematic review and non-linear dose–response meta-analysis of 230 cohort studies with 3.74 million deaths among 30.3 million participants. BMJ 2016, 353, i2156.
12. Di Angelantonio, E.; Bhupathiraju, S.N.; Wormser, D.; Gao, P.; Kaptoge, S.; De Gonzalez, A.B.; Cairns, B.J.; Huxley, R.; Jackson, C.L.; Joshy, G.; Lewington, S. Body-mass index and all-cause mortality: individual-participant-data meta-analysis of 239 prospective studies in four continents. The lancet, 2016, 388(10046), 776-786.
13. Prospective Studies Collaboration. Body-mass index and cause-specific mortality in 900,000 adults: collaborative analyses of 57 prospective studies. The Lancet, 2009, 373(9669), 1083-1096.
14. Sun, H.; Ren, X.; Chen, Z. Association between body mass index and mortality in a prospective cohort of Chinese adults. Medicine 2016, 95, e4327.
15. Kelly, S.J.; Lilley, J.M.; Leonardi-Bee, J. Associations of morbidity in the underweight. Eur J Clin Nutr 2010, 64, 475–482.
16. Woodruff, B.A.; Duffield, A. Anthropometric assessment of nutritional status in adolescent populations in humanitarian emergencies. Eur J Clin Nutr 2002, 56:1108e18.
17. World Health Organization. Guideline: updates on the management of severe acute malnutrition in infants and children. Geneva (Switzerland). 2013, World Health Organization.
18. Mramba, L.; Ngari, M.; Mwangome, M.; Muchai, L.; Bauni, E.; Walker, A.S.; Gibb, D.M.; Fegan, G.; Berkley, J.A. A growth reference for mid upper arm circumference for age among school age children and adolescents, and validation for mortality: growth curve construction and longitudinal cohort study. BMJ 2017, 358.
19. Briend, A.; Garenne, M.; Maire, B.; Fontaine, O.; Dieng, K. (1989). Nutritional status, age and survival: the muscle mass hypothesis. Euro J Clin Nutr 1989, 43(10), 715-726.
20. Ayu, D.R.; Aditiawati, A.; Anzar, J.; Bahar, E. Upper arm circumference measurement for detecting overweight and obesity in children aged 6-7 years. Paediatr Indones. 2017, 57(1):23-9.
21. Chaput, J.P.; Katzmarzyk, P.T.; Barnes, J.D.; Fogelholm, M.; Hu, G.; Kuriyan, R.; Kurpad, A.; Lambert, E.V.; Maher, C.; Maia, J.; Matsudo, V.; Mid-upper arm circumference as a screening tool for identifying children with obesity: a 12-country study. Pediatric obesity, 2017, 12(6), pp.439-445.
22. Reilly, J.J. Mid-upper arm circumference (MUAC): new applications for an old measure. Arch Dis Child 2017, 102(1):1-2.
23. Liu, E.; Spiegelman, D.; Semu, H. Nutritional status and mortality among HIV-infected patients receiving antiretroviral therapy in Tanzania. J Infect Dis 2011, 204, 282–290.
24. Oliveira, I.; Andersen, A.; Furtado, A. Assessment of simple risk markers for early mortality among HIV-infected patients in Guinea-Bissau: a cohort study. BMJ Open 2012, 2, e001587.
25. Gustafson, P.; Gomes, V.F.; Vieira, C.S. Clinical predictors for death in HIV-positive and HIV-negative tuberculosis patients in Guinea-Bissau. Infection 2007, 35, 69–80.
26. Wijnhoven, H.A.; Schilp, J.; de Vet, H.C.; Kruizenga, H.M.; Deeg, D.J.; Ferrucci, L.; Visser, M. Development and validation of criteria for determining undernutrition in community-dwelling older men and women: The Short Nutritional Assessment Questionnaire 65+. Clin Nutr 2012, 31(3), 351-358.
27. Allard, J.P.; Aghdassi, E.; McArthur, M. Nutrition risk factors for survival in the elderly living in Canadian longterm care facilities. J Am Geriatr Soc 2004, 52, 59–65.
28. Olukoya, A.A. Identification of underweight

women by measurement of the arm circumference. Int J Gynaecol Obstet 1990, 31, 231–235.
29. Nguyen, P.; Ramakrishnan, U.; Katz, B.; Gonzalez-Casanova, I.; Lowe, A.E.; Nguyen, H.; Pham, H.; Truong, T.; Nguyen, S.; Martorell, R.; Mid-upper-arm and calf circumferences are useful predictors of underweight in women of reproductive age in northern Vietnam. Food and Nutrition Bulletin 2014, 35(3), 301-311.
30. Sultana, T.; Karim, M.N.; Ahmed, T.; Hossain, M.I. Assessment of under nutrition of Bangladeshi adults using anthropometry: can body mass index be replaced by mid-upper-armcircumference? PLoS One 2015, 10:e0121456.
31. James, W.P.; Mascie-Taylor, G.C; Norgan, N.G.; Bistrian, B.R.; Shetty, P.S.; Ferro-Luzzi, A. The value of arm circumference measurements in assessing chronic energy deficiency in Third World adults. Eur J Clin Nutr 1994, 48:883e94.
32. Stewart, A.; MArfell-Jones, M. International Society for the Advancement of Kinanthropometry. International Standards for Anthropometric Assessment 2011, Glasgow, U.K: ISAK.
33. WHO. Child growth standards: WHO; 2017. http://www.who.int/childgrowth/software/en/. (Accessed 12 January, 2024).
34. Ferro-Luzzi, A.; James, W.P. "Adult Malnutrition: Simple Assessment Techniques for Use in Emergencies." Brit J Nutr 1996, 75(1):3–10.
35. Collins, S. "Using Middle Upper Arm Circumference to Assess Severe Adult Malnutrition during Famine." J Am Med Assoc 1996, 276(5):391–5.
36. James, W.P.; Mascie-Taylor, G.C.; Norgan, N.G.; Bistrian, B.R.; Shetty, P.S.; Ferro-Luzzi, A. The value of arm circumference measurements in assessing chronic energy deficiency in Third World adults. Eur J Clin Nutr 1994, 48(12), 883-894.
37. M. Nwankwo; B. Danborno; S. A. Musa et al. Reference percentiles for mid-upper arm circumference, upper arm muscle and fat areas of Nigerian children and adolescent population aged 0 - 19 years. Rwanda Medical Journal, Vol 81, no. 1, p. 38- 52, 2024. https://dx.doi.org/10.4314/rmj.v81i1.4
38. Dasgupta, A.; Butt, A.; Saha, T.K.; Basu, G.; Chattopadhyay, A.; Mukherjee, A. Assessment of malnutrition among adolescents: can BMI be replaced by MUAC. Ind J Comm Med 2010, 35(2), 276-279.
39. De, K. Assessment of nutritional status of adolescent girls by mid-upper arm circumferences of PaschimMedinipur, India. Primary Health Care 2016, 6, 4.
40. Jeyakumar, A.; Ghugre, P., Gadhave, S. Mid-upper-arm circumference (MUAC) as a simple measure to assess the nutritional status of adolescent girls as compared with BMI. Infant Child Adolesc Nutr 2013, 5, 22–25.
41. Chakraborty, R.; Bose, K.; Bisai, S. Mid-upper arm circumference as a measure of nutritional status among adult Bengalee male slum dwellers of Kolkata, India: relationship with self-reported morbidity. Anthropologischer Anzeiger 2009, 129-137.
42. Bisai, S.; Bose, K. Undernutrition in the Kora Mudi tribal population, West Bengal, India: a comparison of body mass index and mid-upper-arm circumference. Food and nutrition bulletin, 2009, 30(1):63-67.
43. Gartner, A.; Maire, B.; Kameli, Y.; Traissac, P.; Delpeuch, F. Body composition unaltered for African women classified as 'normal but vulnerable' by body mass index and mid-upper-arm-circumference criteria. Eur J Clin Nutr 2001, 55(5):393-399.
44. Das, A.; Saimala, G.; Reddy, N.; Mishra, P.; Giri, R.; Kumar, A.; Raj, A.; Kumar, G.; Chaturvedi, S.; Babu, S.; Srikantiah, S.; Mahapatra, T. Mid-upper arm circumference as a substitute of the body mass index for assessment of nutritional status among adult and adolescent females: learning from an impoverished Indian state. Public health 2020, 179:68- 75.
45. Nwankwo, M.; Danborno, B.; Musa, S.A.; Shehu A.A. Prevalence and associated factors of stunting and thinness among children and adolescents in Nasarawa state: comparison with World Health Organization reference. RMJ 2024, Vol. 81 (1), 38-52, https://dx.doi.org/10.4314/rmj.v81i1.4
46. Sethi, V.; Gupta, N.; Pedgaonkar, S.; Saraswat, A.; Singh, K.D.; Rahman, H.U.; de Wagt, A.; Unisa, S. Mid-upper arm circumference cut-offs for screening thinness and severe thinness in Indian adolescent girls aged 10–19 years in field settings. Public Health Nutrition 2019, 22(12), 2189–2199.
47. Das, P.; Khatun, A.; Bose, K.; Chakraborty, R. (2018). The validity of mid-upper arm circumference as an indicator of low BMI in population screening for undernutrition: a study among adult slum dwellers in eastern India. Public Health Nutrition 2018, 21(14), 2575–2583.