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Accuracy of mid upper arm circumference in detection of obesity among school children in Yenagoa City, South-south region of Nigeria

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Abstract: The search for alternative method that is easier and less cumbersome than body mass index (BMI), for identification of obese individuals has been controversially discussed in recent literature. This study was carried out to determine the accuracy of Mid Upper Arm Circumference (MUAC) compared to BMI.
Method: We recruited 920 children aged 5–18 years from primary and secondary schools in Yenagoa in the Niger Delta region of Nigeria using a multistage random sampling technique. Weight, height and MUAC of the children were measured using standard methods. We calculated BMI, defined obesity as BMI-for-age z-scores >2 and the corresponding cut-off values of MUAC for defining obesity were determined. Sensitivity, specificity, negative predictive values (NPV) and positive predictive values (PPV) of MUAC were determined using BMI as the gold standard. Area Under the ROC (AUC) was also determined to assess MUAC's ability to correctly identify obesity.
Results: MUAC correlated positively with BMI and age, the cut-off values increased with age in both boys and girls. When compared with BMI, using sex and age group specific cut-off for MUAC, the estimated specificities were relatively higher than sensitivities in all age groups. However, the best performance of MUAC for detection of obesity was recorded for girls (AUC = 0.94, 96% CI = 0.89, 0.99) and boys (AUC = 0.89, 95% CI = 0.78, 0.99) in age group 10-14 years. Similarly, the NPV were higher than the PPV.
Conclusion: The MUAC showed remarkably high accuracy for diagnostic and screening use among children aged 10-14 years but inconsistent results in other age groups.

Keywords: body mass index, mid-upper arm circumference, obesity

Introduction

Obesity among children and adolescents is rapidly becoming a global epidemic.[1,2] The estimated prevalence of overweight/obesity in children aged 5-17 years worldwide is 10%, with variation of over 30% in America to <2% in sub-Saharan Africa.[3] In Nigeria, the national prevalence is 1.1%,[4] ranging from 0% to 37.2% in different regions of the country.[5-9] Due to the complications of childhood obesity, it is important to identify children at risk, but unfortunately information on the problem is scarce in Nigeria.
The body mass index (BMI) is the main proxy indicator of body fatness in both children and adults,[10,11] but its use requires equipment and calculations, thus limiting its use in resource poor settings and necessitating the need for a more friendly and reliable method.[12,13] One such method may be the mid-upper arm circumference (MUAC) because it is less affected by the localised accumulation of excess fluid than BMI and it does not require height measurement.[14-16]
Nigeria is on the verge of experiencing an increase in childhood obesity, possibly because the rapidly changing economy and population lifestyle tends towards those of developed countries. A potentially more friendly, faster and easier method of screening for overweight and obesity among young people such as the MUAC needs to be validated. This study was conducted to evaluate the accuracy of MUAC compared to BMI in determining overweight and obesity. It was also intended to determine MUAC cut-off values for defining obesity among school children in Yenagoa, Nigeria's south-south region.

Methods

Study design, settings and population

A cross-sectional design was adopted in this study. School children aged 5 to 18 years were investigated for obesity using anthropometric measurements and at the same time documented their socio-demographic characteristics. Participants were recruited during school hours, minimal physical examination of each child was performed in a dedicated cubicle in each of the schools and strict confidentiality was observed. The study was conducted in the petroleum-rich town of Yenagoa, Nigeria's Niger-Delta region during the months of June to September 2015. Yenagoa is a Local Government Area with an estimated total population of 459,693, of which about 48.3% were children (2015 projection from 2006 census).[17] The adult population are mainly civil servants, traders, and sustenance farmers. According to the 2013 demographic health survey report, the net school attendance rate was 78.1%.[4] The choice of this study area was informed by the anecdotal observation of rapidly changing economy, proliferation of fast foods restaurants and increasing transportation vehicles, and relatively few youth friendly recreational centres for play or physical exercises.

Sample size calculation

The study sample size was calculated using formula for estimating single proportion, an assumed prevalence of childhood obesity of 18.0% reported in two previous publications,[9,18] a margin of error ±5% margin of error, 95% level of confidence and non-response rate of 5%. The calculated number of children required for each of the 4 categories of schools (public primary, private primary, public secondary and private secondary) was 218 giving the minimum total sample size as 872.

Sampling technique

A three-stage random sampling method was used to select two educational zones (Okolobiri and Yenagoa town), schools (16 primary and 16 secondary schools in each zone) and a total of 920 participants out of 91,238 in the school registers, respectively. The number of participants from each school was based on the proportion of the school population in each of the public primary schools, private primary schools, public secondary schools, and private secondary schools, respectively, out of the overall pupil population.

Data collection

The interviewer-administered questionnaire used for this study was designed by the investigators, items were adapted from the 2013 USA Youth Risk Behaviour Surveillance instrument.[19] The questionnaire had four sections: socio-demographic characteristics, parent and family information, child health status, and anthropometric measurements. It was pre-tested in a rural primary and secondary school, as well as an urban primary and secondary school, and this helped modify any noticed difficult or problem area. All students were invited to a meeting in a large hall during the data collection. We explained the purpose of the study to them and assured them of the confidentiality of any voluntary information. The selected participants received consent forms containing detailed explanations of the study and process of voluntary consent to be signed by their parents / caregivers and returned the following day. Furthermore, before the questionnaire was given, we informed the students that their participation was voluntary and obtained accent from each person. Each student was given time to think through and decide on their participation. The investigators were available to give the necessary clarifications to anyone who asked for more information on any part of the questionnaire.

Anthropometric measurements

The investigators measured the weight, height and MUAC using standard methods with the help of research assistants.[14,20] The weight and height were measured at the nearest 0.1 kg and 0.1 cm respectively, while the MUAC was measured at the nearest 0.1 cm with a non-stretchable tape on bare skin at the midpoint between the tip of the olecranon and the acromion process. A battery powered Seca 872 digital floor scale (Seca, Inc., Columbia, MD, USA) was used for weight measurements while height was measured using a standard stadiometer. BMI (kg/m^2) was calculated as weight (kg) divided by the square of the height (m^2). Obesity was defined by the World Health Organization (WHO) 2007 BMI-for-age reference, z score >+2.0.[21,22]

Ethical considerations

Ethical approval was obtained from the State Universal Basic Education Board, State Senior Secondary School Board, and the Ethics Committee of the Federal Medical Centre, Yenagoa. Parents signed the informed consent forms, and assent was obtained from the participants.

Statistical analysis

The z scores for the calculated BMI were generated using the WHO Anthro Plus 2007 software,[23] exported to MS Excel and added to other corresponding anthropometric measures in IBM SPSS statistics version 20 (SPSS Inc., Chicago, IL, USA). Comparisons were made between groups using the Chi square test and the Student t-test, while the Pearson’s correlation coefficient was used to determine the strength of association between two variables. A p value less than 0.05 was considered as statistically significant. For each of the three categories of 5-9 years, 10-14 years and 15-18 years, the different MUAC (cm) cut-off values for obesity corresponding to BMI-for-age z score > + 2.0 were determined using the point of interception of the graphical plots of sensitivity and specificity against MUAC. Thereafter, the Receiver Operating Characteristic (ROC) curves were used to test MUAC’s ability to correctly identify obese children using the BMI as the gold standard as described by Han and colleagues.[24] The sensitivity and specificity of

MUAC as a screening tool for obesity were also calculated for all cut-off points to find the optimal cut-off values.[13] The agreement between MUAC and BMI as method of identifying obesity was assessed using Kappa statistics according to the scale suggested by Altman.[25] Altman proposed Kappa of less than 0.20 as poor agreement, 0.20 to 0.40 as fair agreement, 0.40 to 0.60 as moderate agreement, 0.60 to 0.80 as good agreement and 0.80 to 1.00 as very good agreement.[25] Correct classification means that both MUAC and BMI identified the child as having obesity or not, while misclassification indicates that there is discordance between the two methods.

Results

Characteristics of the study population

There were 920 participants, 403 (43.8%) males and 517 (56.2%) females. The age of the study participants ranged from 5 to 18 years (overall mean age = 11.7±3.0 years). Table 1 shows the mean age and anthropometric measurements by gender of the participants. The ages of the boys and girls were similar ($p = 0.088$). The mean values of weight, MUAC, BMI, and height were significantly higher in girls than in boys ($p < 0.05$).

Table 1: Anthropometric measurements of male and female participants

Variables	Male	Female	p
Age (years)	11.6±3.1	11.9±2.9	0.088
Weight (cm)	39.2±13.7	43.2±14.5	<0.001
MUAC (cm)	21.7±3.8	23.1±4.9	<0.001
BMI (kg/m^2)	19.2±4.0	20.5±4.8	<0.001
Height-for-age z-score	-0.93±1.36	-0.61±1.42	0.001
Weight-for-age z-score	-0.14±1.43	0.08±1.24	0.016
Height (cm)	140.9±16.9	143.4±15.2	0.017
BMI-for-age z-score	0.52±1.34	0.63±1.26	0.215

Prevalence of obesity and correlation between MUAC and other indices

According to the WHO recommended cut-offs for detection of obesity using z-scores, the prevalence rate of obesity in boys and girls was 8.0% and 9.7%, respectively. The prevalence of obesity was not significantly different between girls and boys ($p = 0.436$). Table 2 presents the Pearson correlation coefficients between MUAC, and anthropometric parameters for boys and girls. MUAC showed a strong positive correlation with BMI ($p < 0.001$). In both boys and girls, all the anthropometrics including BMI show positive correlation with MUAC ($p < 0.001$). However, the strongest correlation was shown between weight and MUAC while the correlations between MUAC and height and its z-score were relatively weak.

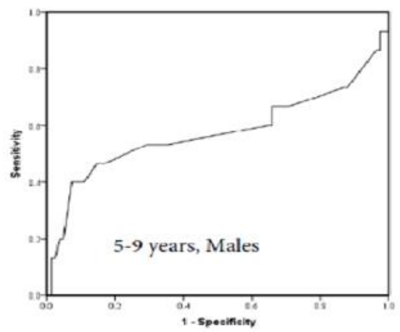
MUAC cut-offs and its abilities to accurately define obesity

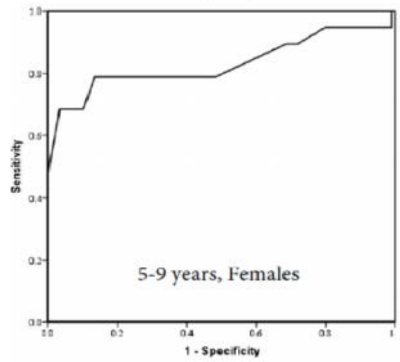
The cut-offs for MUAC, its specificity, sensitivity, positive predictive value (PPV) and negative predictive value (NPV) for different age groups and gender were as shown in Table 3. Table 3 also shows that for both ages and genders, the accuracy levels of MUAC for identifying obesity, using the area under the curve (AUC), was 0.72 (95% CI = 0.59, 0.84), and 0.91 (0.86, 0.97) in the age groups 5-9 years and 10-14 years, respectively ($p < 0.001$). However, these levels of accuracy were not demonstrated when the same analysis was done separately for males and females. Whilst the MUAC significantly detected obesity among female participants in all the three age categories (AUC >0.78), among males, MUAC only showed significant accuracy for detection of obesity in the age group 10-14 years (AUC = 0.89). The MUAC cut-off values for obesity were 20.8 cm, 24.8 cm, and 27.8 cm in girls aged 5-9 years, 10-14 years and 15-18 years respectively, while the cut-offs in boys aged 5-9 years, 10-14 years and 15-18 years were 21.8 cm, 25.4 cm and 27.8 cm, respectively. For the MUAC cut-offs that showed significant AUC, the sensitivities were 82.0% in boys aged 10-14 years; 68.0%, 92.0% and 86.0% in girls aged 5-9 years, 10-14 years and 15-18 years, respectively. Similarly, the specificity was 88.0% in boys aged 10-14 years and approximately 96.0%, 84.0% and 75.0% in girls aged 5-9 years, 10-14 years and 15-18 years, respectively. The positive and negative predictive values for each cut-off point are also shown in Table 3.

Table 2: Relationship between mid-upper-arm circumference and other anthropometric variables by gender

Variables	Male		Female	
	r	p	r	p
Weight (cm)	0.765	<0.001	0.737	<0.001
Height (cm)	0.469	<0.001	0.347	<0.001
Weight-for-age z-score	0.557	<0.001	0.626	<0.001
Height-for-age z-score	0.416	<0.001	0.344	<0.001
BMI-for-age z-score	0.589	<0.001	0.624	<0.001

r = correlation coefficient
*p value < 0.001 in all cases





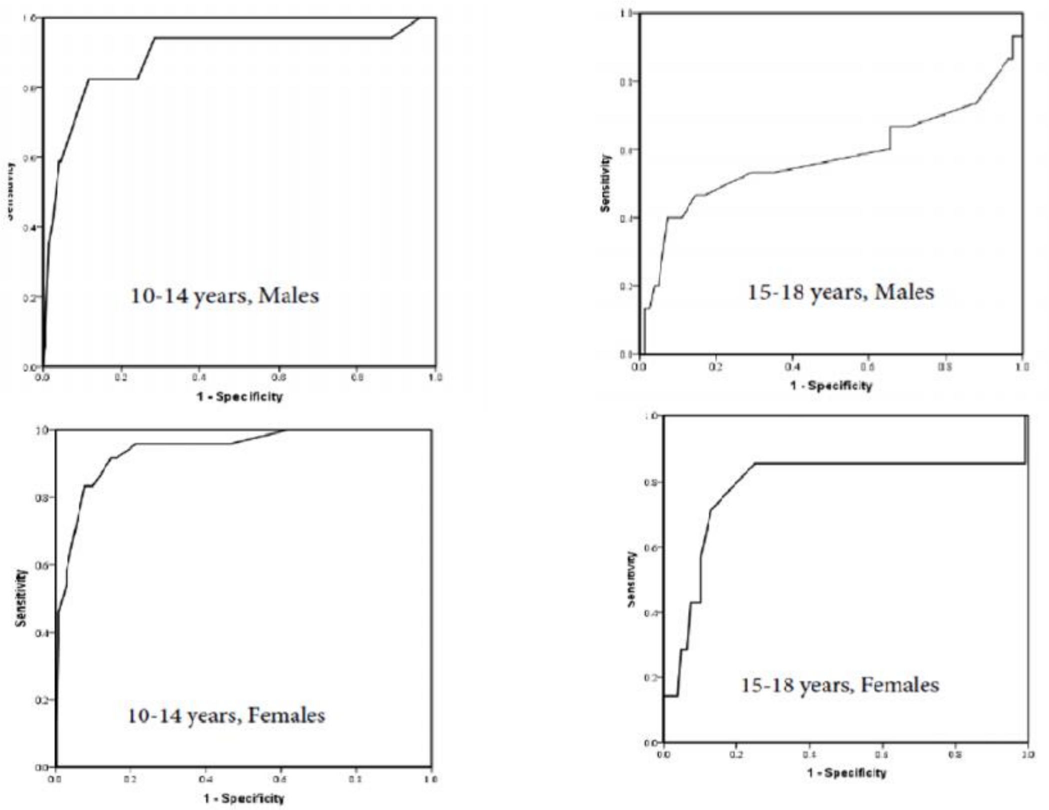


Fig 1: Receiver Operating Curves for MUAC as predictor of BMI-for-age >2.0 z-score among children

Table 3: Area under the ROC curves, optimal cut-off values, sensitivities, and specificities for mid-upper-arm circumference associated with obesity in children

Age (years)	N	True Prevalence (%)	Cut-off (cm)	AUC (95% CI)	p	Sensitivity	Specificity	PPV	NPV
All children									
5-9	205	17.0	22.1	0.72 (0.59, 0.84)	<0.001	0.47 (0.30, 0.65)	0.95 (0.91, 0.98)	0.67 (0.45, 0.84)	0.90 (0.85, 0.94)
10-14	526	8.0	25.6	0.91 (0.86, 0.97)	<0.001	0.88 (0.73, 0.95)	0.86 (0.82, 0.89)	0.35 (0.26, 0.45)	0.99 (0.97, 1.00)
15-18	189	4.0	27.9	0.73 (0.49, 0.96)	0.032	0.75 (0.36, 0.96)	0.76 (0.69, 0.82)	0.12 (0.05, 0.25)	0.99 (0.94, 1.00)
Male									
5-9	97	15.0	21.8	0.58 (0.37, 0.78)	0.351	0.20 (0.05, 0.49)	0.95 (0.87, 0.98)	0.43 (0.12, 0.80)	0.87 (0.77, 0.93)
10-14	232	7.0	25.4	0.89 (0.78, 0.99)	<0.001	0.82 (0.56, 0.95)	0.88 (0.83, 0.92)	0.35 (0.21, 0.52)	0.98 (0.95, 1.00)
15-18	74	1.0	27.8	0.36 (0.22, 0.50)	0.071	0.00 (0.11, 0.95)	0.81 (0.70, 0.88)	0.00 (0.01, 0.24)	0.99 (0.91, 1.00)
Female									
5-9	108	18.0	20.8	0.83 (0.69, 0.97)	<0.001	0.68 (0.43, 0.86)	0.96 (0.88, 0.99)	0.76 (0.50, 0.92)	0.93 (0.86, 0.97)
10-14	294	8.0	24.8	0.94 (0.89, 0.99)	0.024	0.92 (0.72, 0.99)	0.84 (0.79, 0.88)	0.34 (0.23, 0.47)	0.99 (0.97, 1.00)
15-18	115	6.0	27.8	0.78 (0.54, 0.99)	0.012	0.86 (0.42, 0.99)	0.75 (0.66, 0.83)	0.18 (0.08, 0.36)	0.99 (0.92, 1.00)

AUC Z= area under the curve; CI = confidence interval; PPV = Positive predictive value; NPV = Negative predictive value

Agreement between MUAC and BMI

The agreement between MUAC and BMI in classifying children aged 5-18 years in the identification of weight-for-height categories were as shown in Table 4. For all participants, irrespective of gender and age, the Kappa statistics (0.369) suggested a significant but fair agreement between MUAC and BMI. This level of agreement after stratifying the participants by gender revealed a relatively higher Kappa statistics for females (0.422) compared with 0.276 for males suggesting a moderate agreement for female and only fair agreement for male. However, further stratification of participants by age revealed the highest levels of agreement (moderate) were recorded among children in age 10-14 years among boys (0.433) and 5-9 years among girls (0.667).

Table 4: Agreement between MUAC with BMI in the identification of obesity among children

Age group	Correctly identified by MUAC, n(%)	Misclassified as by MUAC, n (%)	Kappa statistic value	p
All children	776 (84.3)	114 (15.7)	0.369	<0.001
Male Children				
All Boys	341 (84.6)	62 (15.4)	0.276	<0.001
5-9	91 (83.5)	16 (16.5)	0.193	0.037
10-14	203 (87.5)	29 (12.5)	0.433	<0.001
15-18	51 (77.0)	17 (22.6)	-0.261	0.587
Female children				
All Girls	435 (84.1)	82 (15.9)	0.422	<0.001
5-9	98 (90.7)	10 (9.3)	0.667	<0.001
10-14	250 (85.0)	44 (15.0)	0.433	<0.001
15-18	87 (75.6)	28 (24.4)	0.222	<0.001

Discussion

This study investigated the use of MUAC in the detection of obesity among Nigerian children aged 5-18 years using the BMI-for-age reference, z score >+2.0 as the gold standard.[21,22] The MUAC strongly correlated positively with BMI and age in this study. The MUAC cut-off values increase with age in both boys and girls. Thus, MUAC can accurately identify obesity in all Nigerian girls aged 5-18 years but only among boys in the ages 10-14 years. In these age categories, the areas under the ROC curve were consistent with robust diagnostic performance and indicated that measurement of MUAC has a good ability to identify children with or without elevated BMI. To our knowledge, this study provides the first MUAC cut-off values for Nigerian children aged 5-18 years.

One of the potential benefits of using MUAC for detection of obesity is that its measurement is not influenced by respiratory movements and postprandial abdominal distension as in the case of waist circumference. Therefore, MUAC may be a good alternative and reliable index for obesity among girls. Our findings agree with the report by Chomtho et al[26] which showed that MUAC correlated strongly with fat mass but weakly with fat-free mass. In that study, the MUAC value explained 63% of variability in total fat mass and only 16% of variability in total fat-free mass in healthy children. A number of direct measurements of body-fat content and its distribution such as dual X-ray absorptiometry can be used to accurately measure degree of obesity, but many of such methods are neither practical nor affordable to people in resource-limited countries like Nigeria. Thus, the use of MUAC provides a cheaper and easy to use alternative method in such settings.

The MUAC cut-offs that produced good accuracy for the different age groups were relatively higher than those reported by Lu et al[13] who reported values of 18.9 – 23.4cm for 7 – 12 year old Han children, and those reported by Craig et al[27] among South African children who reported values of 18.3cm/18.9cm and 18.4cm/18.6cm for 5–9 year olds girls and boys respectively, and 22.5cm/22.8cm and 22.2cm/23.2cm for 10–14 year old girls and boys respectively. These differences in the MUAC cut-offs suggest that children in these three populations had remarkably different arm muscle mass. Another possible explanation for the differences in cut-offs may be the variation in prevalence of obesity (defined by using BMI). A recent systematic review showed that sensitivity and specificity of a test often vary with disease prevalence and this effect is likely to be the result of mechanisms, such as patient spectrum and diagnostic cut-off.[28]
The fact that AUC were excellent for boys aged 10-14 years and girls in all age groups (AUC >0.78) agree with the report by Lu et al.[13] for Han children (0.934 – 0.975) and Craig et al[27] among South African children (0.96 and 0.90 in girls and boys in the 5–9 year old age group; 0.94 and 0.97 in girls and boys in the 10–14 year old age group). The implication of this is that MUAC shows some promise as a reliable method for detection of obesity among children population irrespective of geographical location. However, many studies have shown that body size, which varies by geographical boundaries and ethnicity, is an essential determinant of MUAC in children, and so it is necessary to consider population specific characteristics such as average height to determine whether MUAC is appropriate or not.[29,30]

The results of our data show that, when compared to BMI, the sensitivities of MUAC in screening for obesity in children were sufficiently good but lower than those obtained in other studies. Craig etal[27] observed sensitivity and specificity to be generally high (76 – 97%) in their study of 5 – 14 year old South African children. Similarly, de Almeida et al[16] obtained a sensitivity and specificity of 76.5% and 77.9% respectively in 1 – 5 year old Brazilian children. Lu et al[13] also obtained a sensitivity of 83.8 – 94.5% and 82.5 – 90.2% in Han girls and boys respectively, with a specificity of 81.7 – 94.0% and 89.0 – 95.7% in girls and boys respectively.
Overall, it is evident from the results of this study that specificities and negative predictive values were remarkably greater than sensitivities and positive predictive values, respectively, in all age groups. The high specificities imply that the fraction of those without the obesity correctly identified as negative by the MUAC was higher than the fraction of those with the obesity correctly identified as positive by the MUAC. Therefore, MUAC would be a better tool for diagnostic use than screening. Similarly, the fractions of people with MUAC indicating obesity who actually have the condition as shown by the positive predictive values were lower than those people who actually did not have the condition detected by MUAC as shown by negative predictive values. The relatively lower positive predictive values obtained for MUAC is not surprising as studies have shown that when the prevalence of the disease is low the predictive value of a positive test will also be low.[31]

One major issue that can limit the generalisation of our finding to the entire Niger Delta region of Nigeria is geographical restriction of participants to only residents of Yenagoa Local Government Area. However, the most recent demographic health survey conducted in the region showed that the characteristics of the population in different localities might not be remarkably different.[4] Thus, we speculate that variation in the prevalence of obesity and the ability of MUAC to detect it may not be considerably different across the Niger Delta region. Another limitation is the lack of data on pre- school children. The challenges of collecting accurate data on anthropometry in addition to the fact that MUAC vary considerably even within the same ages being a period of rapid growth, make the use MUAC alone less dependable compared to actual estimation of BMI.[21] Nonetheless, we suggest that the feasibility of including pre-school children and use of MUAC method be considered in future studies.

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