

Determination of overnutrition using mid-upper arm circumference in comparison with bioelectrical impedance analysis in children and adolescents in Benin, Nigeria

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Abstract

Purpose – The prevalence of overweight and obesity in children and adolescents is on the increase in developing countries. Therefore, a cheap, accessible and simple screening tool such as the mid-upper arm circumference (MUAC) is required for the prompt assessment. The purpose of this paper is to determine the usefulness of MUAC in assessing overnutrition in comparison with bioelectrical impedance analysis (BIA).

Design/methodology/approach – Participants included 1,067 children aged 6–18 years recruited from private and public schools in Egor Local Government Area in Benin City, Nigeria. Body fat was estimated by BIA using a Tanita scale, whereas the MUAC was measured with a non-elastic tape. Receiver operating characteristic analysis was used to test the ability of MUAC to determine children and adolescents identified as overweight and obese by BIA.

Findings – The prevalence of overnutrition by MUAC (12.4 percent – overweight 6.0 percent and obesity 6.4 percent) was comparable to that by BIA (12.3 percent – overweight 5.4 percent, obesity 6.9 percent). There was a significant correlation between MUAC and body fat percentage, fat mass, fat mass index and fat-free mass index in both males and females ($p = 0.000$).

Research limitations/implications – This study, in contrast to most other studies on the use of MUAC in the assessment of overnutrition, has the advantage of using BIA cut-offs values against body mass index which does not assess body fat composition. BIA is, however, not the gold standard in the measurement of body fat composition. The optimal MUAC cut-off values of this study may not be representative of the entire country because of its restriction to Benin. Similar studies from different parts of Nigeria will be required to validate this smoothed MUAC percentiles for use in the screening of children and adolescents for overnutrition.

Originality/value – MUAC compares well with BIA in this study and can be a useful, alternative and practical screening tool for assessing obesity in the resource-poor setting.

Keywords Adolescents, Children, Bioelectrical impedance analysis, Mid-upper arm circumference, Overnutrition, Nigeria

Paper type Research paper



Introduction

Overnutrition which consists of overweight and obesity constitutes one of the major contributors to the global burden of non-communicable diseases. The World Health Organization has estimated that non-communicable diseases will become the principal cause of morbidity and mortality within the next few years[1]. The burden of overweight and obesity is on the increase globally which is due largely to a change in the dietary pattern and lifestyle.

More than 1.9bn adults, aged 18 years and older, were overweight, whereas 600mn were obese globally in 2014. About 42mn children less than five years of age were either overweight or obese in the same year[2].

The high burden of undernutrition in developing countries is coexisting with a rising incidence of overnutrition which is estimated to be about 30 percent faster than in richer countries. The prevalence of overweight and obesity in preschool-aged children was 13.7 and 5.25 percent, respectively[3]; in school-aged children it was 7.7 and 3.1 percent, respectively[4]; and in adolescents it was 1.98 and 0.84 percent, respectively[5]. A 30-year systematic review of studies on obesity and overweight in children and adolescents in Nigeria showed a prevalence of 1.0–8.6 percent of overweight and 0.0–2.8 percent of obesity. The studies of children and adolescents combinedly showed a prevalence of 5.0–12.0 percent of overweight and 0.0–5.8 percent of obesity[6].

The rising trend in obesity in developing countries has been attributed to reduced physical activities and nutritional transition from traditional diets rich in fiber to intake of calorie-dense, nutrient-poor foods[7]. Greater affluence with more technology such as television in homes and the ability to purchase fast foods have been linked to overweight[7]. Overweight and obesity in school-aged children in Nigeria were significantly associated with high socioeconomic status (SES), attendance of private schools (mainly affordable to those in high SES), female gender and presence of television in the children's room[8].

Obesity is associated with complications that can occur during childhood and adolescence and persist into adulthood. These complications include hypertension with its attendant risk of long-term cardiovascular diseases and early death. Studies among school-aged children in Nigeria showed a significantly higher proportion of children with blood pressure in the pre-hypertension and hypertension range in obese children[4, 9]. Early detection of overnutrition and institution of measures to prevent complications are of utmost importance.

Body mass index (BMI), which is an indirect method of assessment of body fat, is an acceptable and widely used technique globally. Other indirect methods include mid-upper arm circumference (MUAC), skinfold thickness and waist circumference. The direct methods include bioelectrical impedance analysis (BIA), isotope dilution (hydrometry), dual-energy X-ray absorptiometry and magnetic resonance imaging. The BIA, in contrast to BMI and other indirect methods, can measure body fat percentage from which fat mass and fat-free mass can be measured and has been validated for the use in Nigerian children and adolescents[10].

The MUAC, a simpler indirect method than BMI, is a well-known tool for the assessment of undernutrition in children under the age of 5 but has also been reported to be a useful, alternative and practical screening tool for obesity[11].

Jaiswal *et al.* in India reported MUAC to be highly accurate in identifying obesity in children aged 5–14 years[11]. Chomtho *et al.*[12] reported a strong correlation between MUAC and fat mass compared with fat-free mass in children aged 4.4–13.9 years.

There is a paucity of data in Nigeria on the use of MUAC in the assessment of overnutrition. This study aimed at determining the usefulness of MUAC in the assessment of overnutrition in comparison with BIA among children aged 6–18 years in Egor Local Government Area (LGA) of Edo State in Nigeria.

Methods

This is a cross-sectional study carried out among apparently healthy children aged 6–18 years attending primary and secondary schools in Egor LGA, Benin City, Edo State, Nigeria. There are 37 public primary schools, 13 public secondary schools and 143 approved private nursery, primary and secondary schools within the LGA. The study was conducted between October and December 2017. The sample size was calculated using the formula[13]:

$$n = Z_{(1-\alpha/2)}^2 P(1-P)/d^2,$$

where n is the minimum sample size, $Z_{1-\alpha/2}$ is the confidence interval constant at 95 percentile confidence interval from a table for two-tailed study = 1.96, P is the best estimate of prevalence. A prevalence of 50 percent was used because there are no known references for ages 6–18 years in primary and secondary school pupils in the locality, d is the precision value = 0.03. Hence:

$$n = (1.96)^2(1-0.5)(0.5)/0.03^2 = 1,067.$$

Sampling technique

Subjects were selected using a multi-stage sampling technique.

Of the ten political wards in Egor LGA, 30 percent were selected by the simple random technique. There are 27 private schools and 10 public schools in the three selected wards (Evbotubu, Use and Uselu). Three private and one public school, in keeping with the private to public schools ratio of 3:1 (143:50) in the LGA, were selected from each ward using the simple random sampling technique. A total of nine private and three public schools were selected. The number of pupils to be sampled from each school was determined using the formula:

$$n = a \times b/c,$$

where a is the number of children aged 6–18 years in each school; b is the sample size of the study (1,067), whereas c is the total number of children aged 6–18 years in all the selected schools. The number of children to be sampled from each age group was calculated after obtaining their ages from the class register provided by the school head. The formula $n_1 = a \times b/c$ was used where n_1 is the age sample size; a is the number of each age cohort; b is the obtained sample size from each selected school; and c is the population of children aged 6–18 years in each school.

Selection of subjects

After calculating the age sample size, an arm was picked from the class containing the required age. One arm was picked from Primary 1 and Primary 2 where the six-year-olds were found. The register for the selected arm was obtained and a separate list of male and female pupils was generated following which a number was assigned to each pupil, written in a piece of paper and put in a bag. The required number of pupils was randomly picked separately from the bags containing males and females until the sample size was obtained. The subjects were classified into four age groups to reflect pre-adolescence (6–9 years), early adolescence (10–12 years), mid-adolescence (13–15 years) and late adolescence (16–18 years)[14].

Data collection

A questionnaire which was pretested in another school not selected for the study was used to collect information on the sociodemographic characteristic of the subjects and their families and on the presence of any chronic disease. A general examination was performed

on the subjects while the anthropometry was measured. A Seca stadiometer (model 214; Seca Corp, Hanover, MD, USA) was used to measure the height to the nearest millimeter with the subjects standing erect, bare footed and both feet together. The heels, buttocks and upper part of the back touched the scale. The weight was measured to the nearest 100 g with the Tanita body fat monitor/scale model SC-240 which displays the body weight and body fat percentage. The pupils were weighed in their school uniforms without cardigan or sweater and with all pockets emptied out. The equipment self calibrates after each measurement. The BIA was measured with the Tanita scale. The fat mass was calculated from the body fat percentage and body weight. The fat-free mass is the body weight minus the fat mass. The fat mass index and the fat-free mass index were derived from the fat mass and fat-free mass, respectively, divided by the square of the height. The MUAC was measured midway between the olecranon and acromion process using a non-elastic measuring tape (Chasmors, London) to the nearest millimeter.

The socioeconomic class was calculated using the educational status and occupation of the parents as described by Oyedepi[15].

Ethics

Ethics approval was obtained from the Ethics and Research Committee of the University of Benin Teaching Hospital (ADM/E22/A/VOL.VII/1348). Written permission was obtained from the Education Authority of the Egor LGA, written informed consent was given by the parents/guardians, whereas verbal permission was given by the school heads.

Data analysis

Data were analyzed using Statistical Package for Social Sciences (SPSS) version 21.0 (SPSS for Window Inc., Chicago, IL, USA). Mean, standard deviation, standard error of mean were calculated for quantitative variables such as BIA, MUAC and independent *t*-test was used for the comparison of means. Receiver operating characteristic (ROC) analysis was used to test the ability of MUAC to determine those children and adolescents identified as overweight and obese by BIA. A ROC score is considered as follows: 0.9–1 (excellent), 0.8–0.9 (good), 0.7–0.8 (fair), 0.6–0.7 (poor) and 0.5–0.6 (fail). A test with an area under the curve (AUC) ≥ 0.85 is considered an accurate test[16]. Sensitivity and specificity of MUAC were calculated at all possible cut-off points to find the optimal cut-off values. Predictive values of MUAC were obtained using BIA as standard. The McCarthy reference which defines overfat/overweight as greater than or equal to the 85th percentile of body fat and obesity as greater than or equal to 95th percentile of body fat was used[17]. χ^2 was used in testing the association between overnutrition and gender with the test significance set at $p < 0.05$ and a confidence level of 95.0%.

Results

A total of 1,067 subjects consisting of 538 (50.4 percent) males and 529 (49.6 percent) females with M:F ratio of 1:1 were recruited for the study. In all, 335 (31.4 percent) of the subjects were recruited from public schools, whereas 732 (68.6 percent) were from private schools. The pre-adolescent age group (6–9 years) had the highest representation (30.8 percent), whereas the early adolescent (10–12 years) and late adolescent (16–18 years) age groups had equal and least proportion. Most (42.2 percent) of the subjects belonged to the middle socioeconomic class (SEC), whereas the lower SEC had the least proportion (24.2 percent). Of the 358 subjects in the upper SEC, 83.8 percent were in private schools, whereas 16.2 percent attended public schools.

There was no significant difference, as depicted in Table I, between the mean age of male subjects (12.00 ± 3.77 years) and the female subjects (11.99 ± 3.72 years, $p = 0.941$).

The mean MUAC, percent body fat, fat mass and fat mass index were higher in females than in males and this difference was statistically significant, $p < 0.0001$.

There was no significant difference between the mean weight of male subjects (40.46 ± 15.61 kg) and the female subjects (41.95 ± 15.82 kg, $p = 0.122$).

Conversely, the mean height was higher in males (148.06 ± 19.25 cm) than in females (146.79 ± 16.63 cm) but the difference was not statistically significant ($p = 0.248$), whereas the mean fat-free mass and fat-free mass index were statistically higher in males than females, $p < 0.0001$.

The mean MUAC, as shown in Table II, was statistically higher in females than in males (23.31 ± 4.74 cm vs 22.57 ± 4.67 cm, $p = 0.01$).

The MUAC-smoothed centile chart is shown in Table III. The mean MUAC increases with age in both males and females except for male subjects who were nine years old. At different ages, the mean MUAC of the female subjects was higher than that of the male subjects except for 15–17 years and the difference was statistically significant at ages 7, 9, 12 and 13 years.

The 50th centile value of the MUAC-smoothed centile chart ranged from 17.5 to 28 cm for males and from 17.9 to 28.1 cm for females with peak at age 18 years for both sexes.

The overall prevalence of overweight according to body fat percentage using the McCarthy reference was 5.4 percent (6.0 percent for females and 4.8 percent for males), whereas that of obesity was 6.9 percent (7.2 percent for females and 6.7 percent for males).

Table I.
Mean gender comparison of age and anthropometric indices

Parameter	Male	Female	<i>t</i>	<i>p</i>
Age (years)	12.00 ± 3.77	11.99 ± 3.72	0.074	0.941
Weight (kg)	40.46 ± 15.61	41.95 ± 15.82	1.546	0.122
Height (cm)	148.06 ± 19.25	146.79 ± 16.63	1.157	0.248
Mid-upper arm circumference (cm)	22.57 ± 4.67	23.31 ± 4.74	2.563	0.011*
Body fat (%)	13.30 ± 5.90	21.26 ± 8.49	17.791	0.000*
Fat mass (kg)	5.45 ± 4.14	9.96 ± 7.56	12.092	0.000*
Fat-free mass (kg)	35.01 ± 13.36	31.99 ± 9.79	4.198	0.000*
Fat mass index (kg/m ²)	2.42 ± 1.56	4.31 ± 2.90	13.277	0.000*
Fat-free mass index (kg/m ²)	15.24 ± 2.44	14.42 ± 1.95	6.096	0.000*

Note: * $p < 0.05$

Table II.
MUAC by age and sex

Age (years)	<i>n</i>	Male		<i>n</i>	Female		<i>p</i>
		Mean (cm)	95% CI		Mean (cm)	95% CI	
6	43	17.64 ± 2.09	17.00–18.28	40	18.13 ± 2.05	17.48–18.79	0.28
7	41	17.88 ± 1.56	17.38–18.37	41	18.68 ± 1.77	18.12–19.24	0.03*
8	42	18.98 ± 1.72	18.44–19.52	40	19.37 ± 3.25	18.33–20.41	0.49
9	40	18.63 ± 2.14	17.94–19.31	42	20.25 ± 2.64	19.43–21.08	0.00*
10	43	20.06 ± 2.79	19.20–20.92	39	20.67 ± 2.51	19.85–21.48	0.30
11	40	21.56 ± 3.04	20.59–22.54	42	22.30 ± 3.32	21.26–23.33	0.30
12	38	22.29 ± 2.05	21.62–22.96	43	23.72 ± 3.10	22.77–24.67	0.02*
13	42	22.58 ± 2.51	21.80–23.37	40	24.50 ± 3.30	23.45–25.55	0.00*
14	40	23.75 ± 3.73	22.56–24.94	42	24.98 ± 2.81	24.10–25.85	0.10
15	46	26.61 ± 3.61	25.54–27.68	38	26.61 ± 3.32	25.52–27.70	0.99
16	39	27.35 ± 2.90	26.41–28.28	43	27.08 ± 3.66	25.95–28.21	0.72
17	41	27.85 ± 3.35	26.80–28.91	40	27.73 ± 2.88	26.80–28.65	0.85
18	43	28.08 ± 3.67	26.96–29.21	39	29.20 ± 5.43	27.44–30.96	0.27
Total	538	22.57 ± 4.67	22.18–22.97	529	23.31 ± 4.74	22.91–23.72	0.01

Note: * $p < 0.05$

Age (years)	3rd	5th	10th	25th	50th	75th	85th	90th	95th	97th
<i>Boys</i>										
6	14.7	15.1	15.5	16.0	17.5	18.5	19.2	20.3	23.5	24.0
7	15.0	15.1	16.0	16.5	18.0	19.0	19.5	20.0	21.0	21.0
8	17.0	17.0	17.0	17.9	18.5	20.0	20.5	22.1	23.0	23.4
9	14.7	15.5	16.0	17.0	18.1	20.0	20.9	21.5	23.9	24.0
10	16.7	17.0	17.2	18.5	19.5	20.5	21.9	23.9	26.6	30.1
11	17.1	17.5	18.0	19.1	21.3	23.0	24.4	25.0	29.8	30.8
12	19.1	19.5	19.5	20.4	22.5	24.0	24.5	25.1	26.0	26.0
13	18.6	19.0	19.2	20.5	22.3	24.5	25.6	26.4	26.9	27.7
14	17.1	17.5	18.6	21.1	23.0	26.0	28.9	30.0	30.5	31.3
15	19.2	19.7	20.7	24.0	27.0	29.1	30.5	31.0	32.0	33.4
16	22.2	23.0	24.0	25.5	26.5	29.5	31.0	32.5	33.0	33.0
17	19.7	21.7	24.2	26.0	27.5	30.0	31.7	32.0	34.4	35.2
18	22.0	22.3	23.7	25.5	28.0	30.0	32.7	33.0	36.2	37.7
<i>Girls</i>										
6	14.6	15.0	15.6	17.0	17.9	19.4	20.9	21.0	22.9	23.4
7	14.7	16.5	16.6	17.5	19.0	19.6	20.0	20.9	22.4	23.6
8	16.0	16.0	16.6	17.1	18.8	19.5	22.7	24.5	28.4	29.7
9	17.0	17.1	18.0	18.9	19.5	21.0	22.3	25.9	26.9	27.4
10	17.0	17.0	17.5	19.0	20.5	22.0	23.0	23.5	26.0	27.6
11	15.9	17.1	18.5	20.4	22.0	24.1	25.3	26.4	27.9	32.3
12	17.6	19.0	20.0	21.5	23.0	25.5	26.9	28.0	29.9	30.7
13	19.2	20.0	20.6	22.6	24.3	26.0	27.9	28.5	31.8	34.7
14	19.1	19.7	21.3	24.0	24.8	26.0	28.0	28.9	31.6	32.7
15	20.3	21.9	22.5	24.0	26.5	29.0	30.0	31.0	31.3	35.6
16	20.0	22.2	23.0	24.0	27.0	29.5	30.2	32.0	32.0	36.8
17	23.6	24.0	24.0	26.0	27.0	29.5	30.4	31.5	34.0	35.5
18	20.6	22.0	23.0	25.5	28.1	31.5	36.0	38.0	39.5	42.7

Table III.
MUAC-smoothed
centiles by
sex and age

The prevalence of overweight and obesity was higher, although not significantly, in females than in males (overweight, $\chi^2 = 0.768$, $p = 0.381$; obesity, $\chi^2 = 0.100$, $p = 0.752$). The prevalence of overnutrition was 12.3 percent for the study subjects, 13.2 percent for females (70 females) and 11.5 percent for males (62 males), and this difference was not statistically significant ($\chi^2 = 0.72$, $p = 0.39$). The results are shown in Table IV.

Age group (years)	Male		Over weight				Male		Obesity			
	(n)	%	(n)	%	χ^2	p	(n)	%	(n)	%	χ^2	p
<i>Percentage body fat</i>												
6-9	3 (166)	1.8	7 (163)	4.3	1.726	0.189	13 (166)	7.8	4 (163)	2.5	4.853	0.028*
10-12	13 (121)	10.7	9 (124)	7.3	0.910	0.340	8 (121)	6.6	13 (124)	10.5	1.172	0.279
13-15	3 (128)	2.3	6 (120)	5.0	1.250	0.264	5 (128)	3.9	11 (120)	9.2	2.840	0.092
16-18	7 (123)	5.7	10 (122)	8.2	0.596	0.440	10 (123)	8.1	10 (122)	8.2	0.000	0.985
Total	26 (538)	4.8	32 (529)	6.0	0.768	0.381	36 (538)	6.7	38 (529)	7.2	0.100	0.752
<i>MUAC</i>												
6-9	7 (166)	4.2	11 (163)	6.7	1.019	0.313	5 (166)	3.0	6 (163)	3.7	0.114	0.736
10-12	5 (121)	4.1	6 (124)	4.8	0.071	0.789	4 (121)	3.3	2 (124)	1.6	0.735	0.391
13-15	6 (128)	4.7	10 (120)	8.3	1.364	0.243	3 (128)	2.3	10 (120)	8.3	4.473	0.034*
16-18	5 (123)	4.1	14 (122)	11.5	4.702	0.030	11 (123)	8.9	27 (122)	22.1	8.129	0.004*
Total	23 (538)	4.3	41 (529)	7.8	5.714	0.017	23 (538)	4.3	45 (529)	8.5	8.004	0.005*

Note: * $p < 0.05$

Table IV.
Age- and gender-
specific prevalence of
overweight and
obesity according to
BIA and MUAC

The overall prevalence of overweight according to MUAC generated from the smoothed centile chart was 6.0 percent. There was a statistically significant difference between the prevalence of overweight in females and males (7.8 percent vs 4.3 percent, $\chi^2 = 5.714$, $p = 0.017$). The overall prevalence of obesity according to MUAC was 6.4 percent and was statistically higher in females (8.5 percent vs 4.3 percent, $\chi^2 = 8.004$, $p = 0.005$). The prevalence of overnutrition in the study subjects by MUAC was 12.4 percent, with females having a statistically higher prevalence (16.3 percent vs 8.6 percent, $\chi^2 = 14.62$, $p = 0.00$) than males. The prevalence of overnutrition using MUAC (12.4 percent) was comparable with that of BIA (12.3 percent).

The AUC, cut-off value, sensitivity and specificity for each age and gender are shown in Table V. The AUC for MUAC was statistically significant in both genders in most ages.

The AUC was good to excellent in most subjects except in males aged 15–17 years and females within the ages of 16 and 18 years. Sensitivity was relatively high in all ages except in males aged 7 and 12 years and females aged 7 and 17 years. Specificity was relatively high in all ages except in males aged 16 and 17 years. There was no subject in the nine-year-old male subjects that were overweight or obese. The MUAC cut-off values for elevated body fat percentage were calculated to be approximately 18.75–31.5 cm in males and females.

There was a significant correlation between MUAC and body fat percentage ($r = 0.183$, $p = 0.000$; $r = 0.780$, $p = 0.000$) fat mass ($r = 0.667$, $p = 0.000$; $r = 0.866$, $p = 0.000$) fat mass

Age (years)	<i>n</i>	AUC (95% CI)	<i>p</i> -value	Cut-off	Sensitivity (%)	Specificity (%)	LR+	LR-
<i>Boys</i>								
6	43	0.86 (0.67–1.00)	0.011	18.75	80.0	86.2	5.80	0.23
7	41	0.83 (0.64–1.00)	0.020	19.75	60.0	94.4	10.71	0.42
8	42	0.99 (0.97–1.00)	0.020	22.75	100.0	97.5	40.00	0.00
9	40	n/a						
10	43	1.00 (1.00–1.00)	0.004	24.75	100.0	100.0	0.00	0.00
11	40	1.00 (1.00–1.00)	0.004	25.50	100.0	100.0	0.00	0.00
12	38	0.81 (0.57–1.00)	0.083	24.25	66.7	85.7	4.66	0.39
13	42	0.89 (0.79–0.99)	0.187	25.50	100.0	87.8	8.20	0.00
14	40	0.85 (0.73–0.97)	0.045	25.75	100.0	75.7	4.12	0.00
15	46	0.79 (0.54–1.00)	0.036	30.00	80.0	85.4	5.48	0.23
16	39	0.62 (0.38–0.85)	0.401	26.25	80.0	52.9	1.70	0.38
17	41	0.66 (0.43–0.89)	0.256	27.75	80.0	55.6	1.80	0.36
18	43	0.97 (0.93–1.00)	0.001	31.50	100.0	94.6	18.52	0.00
<i>Girls</i>								
6	40	0.99 (0.95–1.00)	0.002	20.75	100.0	94.4	17.86	0.00
7	41	0.80 (0.47–1.00)	0.089	21.75	66.7	100.0	0.00	0.33
8	40	0.98 (0.95–1.00)	0.001	22.00	100.0	97.1	34.48	0.00
9	42	1.00(1.00–1.00)	0.001	24.00	100.0	100.0	0.00	0.00
10	39	0.92 (0.80–1.00)	0.001	22.25	80.0	96.6	23.53	0.21
11	42	0.98 (0.93–1.00)	0.025	26.75	100.0	97.3	37.04	0.00
12	43	0.99 (0.96–1.00)	0.001	27.75	100.0	97.4	38.46	0.00
13	40	0.85 (0.68–1.00)	0.023	25.75	75.0	72.2	2.70	0.35
14	42	0.94 (0.82–1.00)	0.013	25.80	100.0	76.9	4.33	0.00
15	38	0.87 (0.75–0.98)	0.001	27.25	84.6	80.0	4.23	0.19
16	43	0.78 (0.55–1.00)	0.019	28.75	71.4	72.2	2.57	0.40
17	40	0.77 (0.58–0.95)	0.013	29.00	60.0	76.7	2.58	0.52
18	39	0.88 (0.77–0.99)	0.001	26.25	87.5	80.0	4.38	0.16

Table V. Area under the curves, optimal cut-off values, sensitivities and specificities for mid-upper arm circumference associated with overweight/obesity in boys and girls

Notes: The categories used to summarize accuracy of AUC in ROC analysis were as follows: excellent (0.9–1), good (0.8–0.9), fair (0.7–0.8), poor (0.6–0.7) and fail (0.5–0.6). A test with an AUC ≥ 0.85 is generally considered an accurate test[16]

index ($r = 0.437, p = 0.000; r = 0.791, p = 0.000$) and fat-free mass index ($r = 0.838, r = 0.000; r = 0.735, p = 0.000$) in both males and females, respectively. Body fat percentage, fat mass and fat mass index correlated better with MUAC in females, whereas fat-free mass index correlated better with MUAC in males.

Discussion

This study set out to assess the usefulness of MUAC in comparison with BIA in the assessment of overnutrition which consists of overweight and obesity. The prevalence of overnutrition as estimated by MUAC (12.4 percent) was comparable to the 12.3 percent by BIA. Despite the equal prevalence of overnutrition by both the methods, MUAC tended to slightly underestimate obesity (6.4 percent) in comparison to BIA (6.9 percent). The above finding suggests that MUAC can be a cheap, simple, available, easy to measure and effective indirect method for the assessment of overnutrition in the community. No other study, to the best of the authors' knowledge, has reported the prevalence of overnutrition using MUAC for comparison with our findings. The prevalence of obesity obtained by MUAC (6.9 percent) and BIA (6.4 percent) is similar to the findings of El-Hazmi *et al.* in Saudi Arabia[18] and Sadoh *et al.* in Benin City, Nigeria[9]. A higher prevalence of 17.2 percent was, however, reported by Cheryl *et al.* in the USA[19], whereas a lower prevalence of 3.3 percent was reported in Pakistan[20]. The variation in the prevalence of obesity from the various studies can be attributed to the dietary pattern and level of physical activities which differ within and between countries and regions. The methods of assessment for obesity may also contribute to the difference in prevalence rates.

The mean MUAC of 23.31 ± 4.74 cm in females was statistically higher than the 22.57 ± 4.67 cm found in males which is comparable to the 23.5 ± 3.7 cm and 20.6 ± 3.1 cm reported by Chomtho *et al.* in females and males, respectively[12]. Jaiswal *et al.*[11] similarly reported a higher mean MUAC in females but the values were lower than that were reported in this study. This difference might be due to the age group of 5–14 years studied by Jaiswal *et al.* in contrast to the age group of 6–18 years in this study. Since MUAC increases with age, it follows that the mean value should be lower in the younger age group. The mean MUAC in this study increased with increasing age for both males and females except for nine-year-old males where a decrease was observed. The reason for this finding is not quite apparent.

In contrast to this study, Lu *et al.*[21] reported a higher mean MUAC among males in Han, China (20.9 ± 3.7 cm vs 20.2 ± 3.2 cm, $p < 0.001$). The reason for this was not given by the authors but Zhai *et al.*[22] with similar findings in a study in China noted a traditional, societal preference for male children who are favored to enjoy more of the family resources.

The AUC values for optimal cut-off values of MUAC in the assessment of overnutrition showed high sensitivity and specificity for males and females for most ages. The area under the ROC curve values ranged between 0.62 and 1 with most subjects in the range of 0.8–1. This means 62–100 percent of the time a randomly selected overweight/obese child, based on MUAC, has a body fat percentage greater than that of a randomly selected child of normal adiposity. This finding corroborates previous studies stating that MUAC can be an alternative and reliable index in the assessment of overnutrition especially in the resource-poor setting [23–26]. Similar findings were reported by Craig *et al.*[23] in Black South African children and Mazicioglu *et al.*[24] in Turkish children. It was, however, observed that the accuracy level was higher in females (AUC ≥ 0.85) than males. A similar observation was reported by Craig *et al.* especially in males aged 5–9 years. However, much higher accuracy was observed with no gender difference when MUAC was correlated with BMI in the same subjects[23]. No explanation was proposed for this finding. The positive likelihood ratios for the females which ranged from 18–38 except in middle and late adolescents (ranged from 2–4) further support the better performance of MUAC in females than males with a positive likelihood ratio ranging from 2–6 except in 6, 7 and 18-year olds. The AUC values were less accurate in late adolescents. Contrary to the higher accuracy of MUAC with AUC values between 0.8 and 1 in

the middle and late adolescent age group in the study by Mazicioglu *et al.* in Turkey[24], this study observed a poorer performance in subjects aged 16–17 years. No plausible reason could be ascribed to this finding but of note is the fact that MUAC cut-offs were obtained using BIA cut-off values in this study, whereas BMI was used by Mazicioglu *et al.*

There was a strong positive correlation between MUAC and fat mass and fat mass index as measured by BIA especially in females ($r = 0.87, 0.79$). The correlation between MUAC and fat mass and fat mass index was weaker in males ($r = 0.67$ and 0.44 , respectively). The MUAC, on the other hand, showed a higher correlation with fat-free mass index in males than females. A similar finding was reported by Clomtho *et al.*[12] in the UK. The correlation between MUAC and body fat percentage was weaker in males ($r = 0.183$) than in females ($r = 0.780$). These findings may be attributed to the significant sexual difference in the muscle and fat distribution patterns between males and females due to hormonal influence[25]. Fat-free mass may be more accountable for an increase in MUAC in males, whereas fat mass may be more implicated in females.

The smoothed MUAC percentile for children aged 6–18 years in this study, to the best of the authors' knowledge, is the first in Nigeria for the assessment of overnutrition in children and adolescents. The P_{50} for males ranged from 17.5 cm in the 6-year olds to 28.0 cm in the 18-year olds, whereas that of the females ranged from 17.9 cm to 28.1 cm. The values obtained from the US MUAC[26] reference chart was comparable in six-year-olds to that obtained in this study in both sexes (17.5 vs 17.7 cm in males; 17.9 vs 17.8 cm in females). Males had a slightly higher value than those in our study for aged 18 years (29.4 vs 28 cm), whereas females had slightly lower value than those in our study (26.3 vs 28.1 cm). This difference may infer that the increase in MUAC with age is more marked in males than females in late adolescence. No plausible reason could be ascribed to this finding. Despite a significant difference in the prevalence of overweight and obesity using MUAC in this study, the use of body fat percentage did not show any significant difference. No previous study, to the best of the authors' knowledge, has reported this finding previously. This finding emphasizes the need for caution and inclusion of the tool of assessment in the comparison of the prevalence of overnutrition within and between different populations.

Limitations

This study in contrast to most other studies on the use of MUAC in the assessment of overnutrition has the advantage of using BIA cut-offs values as against BMI which does not assess body fat composition. BIA is, however, not the gold standard in the measurement of body fat composition. The optimal MUAC cut-off values of this study may not be representative of the entire country because of its restriction to Benin. Similar studies from different parts of Nigeria will be required to validate this smoothed MUAC percentiles for use in the screening of children and adolescents for overnutrition.

Conclusion

This study showed a remarkable comparison between MUAC and BIA in the assessment of overnutrition in children and adolescents. MUAC has the potential for use as a proxy for the assessment of overnutrition in resource-poor settings.

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