Rwanda Medical Journal RMJ

ORIGINAL ARTICLE Open Access

Reference percentiles for mid-upper arm circumference, upper arm muscle and fat areas of Nigerian children and adolescent population aged 0 – 19 years

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ABSTRACT

INTRODUCTION: Mid-upper arm circumference (MUAC) has commonly been used for many years as an alternative nutritional status index in field settings, yet estimates of percentile range for healthy children and adolescents have not been documented in Nigeria. We construct reference curves for MUAC and its derived measures of upper arm muscle area (UAMA), upper arm fat area (UAFA) and present sex- and age-specific MUAC, UAMA and UAFA values for children and adolescents.

METHODS: Natural cubic splines were fitted by maximum penalized likelihood to develop centile curves for MUAC, UAMA and UAFA and the LMS coefficients necessary to estimate the z-score specific to each age and gender were presented. MUAC, UAMA and UAFA reference curves of US children and adolescents were used for comparison.

RESULTS: The centiles of MUAC, UAMA and UAFA increased with age. However, these centile curves show significant sex-specific differences for boys and girls aged ≥ 10, ≥ 14.5 and ≥ 4.5 years of age, respectively. Compared to the US reference, the percentiles of MUAC, UAMA and MUAC are generally lower.

CONCLUSION: In this study, we have presented a reference set of curves and tables for MUAC and its measures for healthy children and adolescents.

Keywords: Percentiles, Nutritional status, LMS method, Anthropometric measures, Nigeria

INTRODUCTION

Anthropometric measure is one approach to assess nutritional status based on physical measurements such as mid-upper arm circumference (MUAC), height or weight (specific to age and sex). It has the benefit of being inexpensive, non-invasive and quick to collect. Anthropometric measures are useful both at individual and population levels. Anthropometric measures at the individual level can be used to evaluate impaired health or nutritional status. Such insight can be useful for screening children in need of interventions or evaluating responses to interventions. However,

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Received: 23th September 2023; **Initial decision given:** 24th December 2023; **Revised manuscript received:** 15th January 2024; **Accepted:** 29th February 2024.
 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. 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

anthropometric measures can be used at the population level to evaluate the nutritional status of a community, region, country, or the socioeconomic status and the impact of undernutrition. Therefore, such monitoring of nutritional status can serve as an invaluable source of information when planning for health and nutritional interventions.

MUAC measures the diameter of the upper arm and along with triceps skinfold thickness (TSFT) gauges both subcutaneous fat stores and muscle mass [1,2]. The measurement of MUAC has been used for children and occasionally applied to pregnant women to rapidly assess nutritional status [3]. Because its measurement is simple and requires minimal equipment, MUAC can serve as an alternative index of nutritional status, especially in situations where measurements of height, weight, or age are not feasible to collect or in cases of bedbound patients or amputated patients.

In 2006, the WHO published growth standards for children < 5 years old, whereas, in 2007, they published growth references for schoolchildren and adolescents aged 5 – 19 using height, weight and body mass index (BMI). Although the WHO did not include the MUAC in the 2007 growth charts for schoolchildren and adolescents aged 5 – 19 years [4,5], the Multicentre Growth Reference Study Group considered it for children 0 – 59 months [5]. However, only limited reference data (6 – 59 months of age) for MUAC have been published. In children aged 0 – 59 months old, the WHO/UNICEF joint statement recommends the use of MUAC and weight-for-height z score (WHZ) with cut-off points < 115 mm and <-3, respectively for identification of severe wasting [6,7]. However, the data between these two indicators are inconsistent when classifying different children as severely wasted [8,9]. Additionally, the indicators predict mortality risk in children differently, with MUAC having better predictive performance than WHZ [10-12].

MUAC has started to gain traction ever since it was recommended to field operations as the mainstay indicator for screening and admission to the community-based management of acute malnutrition (CMAM) program [13], aimed at treating children with severe acute malnutrition (SAM).

Recently, analysis of MUAC body composition and its derivative outcome indicators; upper arm muscle area (UAMA) and upper arm fat area (UAFA) references have been published [14] among Argentinian children and adolescents, similar to the one earlier published by Frisancho (2008) and Addo et al. (2017) of children and adolescents in the US [15,16]. In Nigeria, to our knowledge, no reference values of MUAC, UAMA and UAFA of children and adolescents have been published, thereby underscoring the huge gap in data in the largest black African countries in the world.

In the present study, we aimed to develop reference curves for MUAC and its derivative measures UAMA and UAFA from Nigerian children and adolescents to be used to assess nutritional status. We further compared selected centile ranges of Nigerian children and adolescents to those of published reference values of the US.

METHODS

Study Design

The study was cross-sectional and were collected from schoolchildren and adolescents aged 0 – 19 years old. Anthropometric measurements and data on sociodemographics were collected during the study.

Data used for the present study were obtained from daycare, nursery, primary and secondary schools in Lafia (Nasarawa state capital) and Doma local government areas of Nasarawa State, Nigeria, from 2018 to 2019. Lafia was regarded as an urban setting, whereas Doma, was a rural setting. Parents of participants in this study self-identified their ethnic groups as Alago, Eggon, Migili, Mada, Rindei, Agatu, Afo, Gwandara, Baribari, Bassa, Jukun, Egbira, Kanuri, Hausa, Ninzom, Fulani and Gbagyi. The distance between Lafia and Doma is 24 km. Houses in Lafia have electricity and motorized boreholes, while those in Doma rarely have electricity (depend mostly on generators) or running water; water for domestic chores was collected from the river or hand-dug water wells. A few households in Lafia had pit toilets and most water closets, but the majority of households in Doma use open defaecation and pit toilets. Also, the occupation of parents of subjects in Lafia include civil servants, trading, farming, applicants and housewives, but in Doma, most parents report farming as their occupation; cereals and yam tubers are their staple crops. As expected, parents of children in Doma are predominantly illiterate compared to those in Lafia. The research protocol was reviewed and approved by Ahmadu Bello University Ethics Committee on the Use of Human Subjects in Research.

Anthropometry

Anthropometric measurements on each subject were collected following standardized procedures [17]. Mid-upper arm circumference (MUAC) was measured to the nearest 0.1 cm using a flexible tape measure on the right arm, midway between the acromion and olecranon processes of the ulna and triceps skinfold was measured to the nearest 0.5 mm using a Lange calliper. MUAC was collected in duplicate and triceps skinfold in triplicate and their average constituted the analytic values.

The above measures were used to calculate upper arm muscle area (UAMA), upper arm fat area (UAFA) and upper arm area (UAA) as follow:

UAMA (cm^2) = $(\text{MUAC} - \pi \times \text{triceps skinfold})^2 \div 4\pi$
($\pi = 3.1416$) [18]
UAA (cm^2) = $\pi D^2 \div 4$ [1]
Where D = upper arm girth, defined as
MUAC ÷ π [19]
UAFA was therefore calculated as the difference between UAA and the UAMA
UAFA (cm^2) = UAA – UAMA [18]

We analysed MUAC and triceps skinfold data collected from prenursery, nursery, primary, junior and senior secondary schools from September 2018 and December 2019. The 3rd, 10th, 25th, 50th, 70th, 90th and 97th percentiles for MUAC, UAMA and UAFA of children and adolescents were graphically represented.

The WHO (2007) growth reference was used to investigate the independent effects of BMI status on MUAC during growth by generating reference values for various categories of nutritional status using BMI-for-age (BAZ); severe thinness (< - 3 z-score) and moderate thinness (<-2 z-score) [20]. The BAZ scores were generated for children and adolescents aged 5 – 19 years using the WHO 2007 SPSS macros. The application automatically generates variables for normally distributed data but flags outlying values. The outlying values are excluded from further analyses. To further increase the quality of the data, sex and age-specific boxplots and the Shapiro-Wilk test were used to test the normality of the data.

The reference ranges for MUAC, UAMA and UAFA for US children and adolescents published by Addo et al. (2017) were used for comparisons [16]. Here the MUAC, UAMA and UAFA distributions by age are compared focusing on centile curves for the median; 3rd and 97th centiles were used as extreme centiles.

Statistical Analysis

Data was analyzed by the LMS method to model age- and sex-specific percentile curves [21]. To normalize the data at each age and sex, a Box-Cox power transformation was used. We used natural cubic spline with knots at each specific age and fitted by maximum penalized likelihood to generate three smooth curves summarized by the Box-Cox power for skewness, L(t); median, M(t) and the coefficient of variation, S(t). Percentile (P) curves at age t were then generated with the following expression:

$$P_{100\alpha}(t) = M(t)\,[1 + L(t)S(t)Z_\alpha]^{1/L(t)}$$

Inverting the formula above expresses a subject's (y = MUAC/UAMA/UAFA) as a Z-score:

$$Z = \frac{(y/M)^L - 1}{L \times S}$$

In which Z_α represents the normal equivalent deviation for tail area α, and $P_{100\alpha}$ (t) denotes the percentile for Z_α. Equivalent degree of freedom (edf) for the three smoothing parameters L(t), M(t) and S(t) which measure the extent and complexity of smoothing desired, were generated separately for MUAC, UAMA and UAFA and for boys and girls. The fit of each model was first done by visual inspection of the centile curves, and then the goodness of fit was evaluated with Q-tests [22-24]. The Q-tests show the adequacy of the edf for the L, M, and S curves by determining whether or not the Z-scores are normally distributed independently of age. The LMS model was fitted using the LMSchartmaker Pro version 2.54 program (Medical Research Council, London, UK, 2011). All other statistical analyses were conducted with Statistical Package for the Social Sciences (IBM SPSS Incorp., Illinois, Chicago, USA) version 26 for Windows and all statistical analyses were two-tailed and a P-value <0.05 was considered as the limit of significance. The normality of distribution was tested using boxplots and the Shapiro-Wilk test.

RESULTS

The present study included 7,780 children and adolescents (3,854 boys and 3,926 girls) aged 0 – 19 years. Tables 1 – 3 and the corresponding Figures 1 – 3 show age- and sex-specific smoothed

Table 1: Descriptive statistics of absolute height, weight, and body mass index by age and sex

	MUAC (cm)																
	Boys								Girls								
Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th	L	S	3rd	10th	25th	(M)	75th	90th	97th
0 – 0.5	0.0993	0.1177	10.94	11.86	12.84	13.8876	15.02	16.23	17.53	-0.7205	0.1115	11.09	11.85	12.69	13.6439	14.73	15.97	17.40
1.00 – 1.49	0.0480	0.1142	11.24	12.14	13.11	14.1445	15.26	16.46	17.75	-0.7108	0.1076	11.36	12.11	12.94	13.8794	14.94	16.15	17.53
1.50 – 1.99	-0.0031	0.1107	11.54	12.42	13.37	14.3947	15.50	16.69	17.96	-0.7005	0.1037	11.63	12.37	13.19	14.1146	15.15	16.32	17.66
2.00 – 2.49	-0.0537	0.1073	11.82	12.69	13.62	14.6315	15.72	16.89	18.16	-0.6889	0.0999	11.90	12.63	13.44	14.3486	15.36	16.50	17.79
2.50 – 2.99	-0.1031	0.1040	12.09	12.94	13.86	14.8508	15.92	17.08	18.33	-0.6756	0.0963	12.17	12.89	13.69	14.5808	15.57	16.68	17.92
3.00 – 3.49	-0.1510	0.1009	12.34	13.18	14.08	15.0523	16.10	17.24	18.48	-0.6600	0.0929	12.43	13.15	13.94	14.8106	15.78	16.85	18.06
3.50 – 3.99	-0.1968	0.0979	12.57	13.39	14.28	15.2371	16.27	17.39	18.60	-0.6419	0.0899	12.68	13.40	14.18	15.0351	15.98	17.03	18.20
4.00 – 4.49	-0.2401	0.0951	12.79	13.60	14.47	15.4084	16.42	17.52	18.72	-0.6206	0.0872	12.92	13.63	14.40	15.2499	16.18	17.21	18.34
4.50 – 4.99	-0.2805	0.0925	13.00	13.79	14.65	15.5714	16.57	17.65	18.83	-0.5959	0.0851	13.14	13.85	14.62	15.4543	16.37	17.38	18.49
5.00 – 5.49	-0.3178	0.0901	13.20	13.98	14.82	15.7298	16.71	17.78	18.94	-0.5674	0.0836	13.34	14.05	14.82	15.6518	16.56	17.56	18.66
5.50 – 5.99	-0.3516	0.0880	13.39	14.16	14.99	15.8890	16.86	17.91	19.06	-0.5347	0.0830	13.52	14.23	15.01	15.8469	16.76	17.76	18.85
6.00 – 6.49	-0.3816	0.0863	13.58	14.35	15.17	16.0554	17.02	18.06	19.19	-0.4977	0.0830	13.68	14.40	15.19	16.0434	16.97	17.98	19.08
6.50 – 6.99	-0.4081	0.0849	13.78	14.53	15.35	16.2337	17.19	18.23	19.36	-0.4564	0.0837	13.83	14.57	15.38	16.2519	17.20	18.23	19.35
7.00 – 7.49	-0.4314	0.0839	13.97	14.72	15.54	16.4243	17.38	18.42	19.55	-0.4102	0.0850	13.98	14.75	15.58	16.4784	17.45	18.51	19.65
7.50 – 7.99	-0.4517	0.0833	14.16	14.92	15.74	16.6267	17.59	18.63	19.77	-0.3589	0.0866	14.14	14.94	15.80	16.7267	17.73	18.82	20.00
8.00 – 8.49	-0.4692	0.0832	14.35	15.12	15.95	16.8426	17.82	18.87	20.03	-0.3029	0.0885	14.31	15.14	16.03	16.9992	18.04	19.17	20.39
8.50 – 8.99	-0.4842	0.0834	14.54	15.32	16.16	17.0752	18.07	19.14	20.32	-0.2429	0.0907	14.48	15.35	16.29	17.2946	18.38	19.55	20.82
9.00 – 9.49	-0.4965	0.0840	14.74	15.53	16.39	17.3246	18.34	19.44	20.65	-0.1798	0.0931	14.67	15.58	16.56	17.6121	18.75	19.97	21.28
9.50 – 9.99	-0.5053	0.0851	14.94	15.75	16.63	17.5871	18.63	19.77	21.01	-0.1147	0.0956	14.86	15.82	16.85	17.9592	19.15	20.42	21.79
10.00 – 10.49	-0.5093	0.0864	15.13	15.97	16.87	17.8608	18.94	20.11	21.40	-0.0488	0.0982	15.08	16.10	17.18	18.3396	19.58	20.91	22.34
10.50 – 10.99	-0.5078	0.0881	15.33	16.19	17.13	18.1483	19.26	20.49	21.83	0.0166	0.1005	15.34	16.40	17.54	18.7563	20.06	21.44	22.93
11.00 – 11.49	-0.4998	0.0900	15.53	16.42	17.39	18.4514	19.61	20.88	22.28	0.0814	0.1026	15.62	16.74	17.93	19.2077	20.56	22.01	23.54
11.50 – 11.99	-0.4843	0.0921	15.73	16.66	17.67	18.7707	19.98	21.30	22.77	0.1466	0.1044	15.92	17.10	18.35	19.6832	21.09	22.59	24.18
12.00 – 12.49	-0.4600	0.0944	15.94	16.91	17.96	19.1083	20.37	21.75	23.28	0.2134	0.1058	16.24	17.48	18.78	20.1679	21.63	23.18	24.81
12.50 – 12.99	-0.4260	0.0967	16.16	17.17	18.27	19.4663	20.78	22.23	23.82	0.2827	0.1068	16.56	17.85	19.21	20.6477	22.16	23.74	25.41
13.00 – 13.49	-0.3807	0.0990	16.39	17.44	18.59	19.8433	21.22	22.72	24.38	0.3555	0.1071	16.90	18.23	19.64	21.1106	22.65	24.26	25.95
13.50 – 13.99	-0.3231	0.1012	16.64	17.73	18.93	20.2384	21.67	23.23	24.95	0.4322	0.1065	17.24	18.61	20.05	21.5531	23.12	24.74	26.43
14.00 – 14.49	-0.2534	0.1032	16.89	18.04	19.29	20.6524	22.14	23.76	25.53	0.5124	0.1054	17.59	19.00	20.46	21.9783	23.55	25.17	26.85
14.50 – 14.99	-0.1722	0.1050	17.16	18.36	19.67	21.0884	22.63	24.30	26.12	0.5956	0.1037	17.94	19.38	20.86	22.3869	23.96	25.57	27.22
15.00 – 15.49	-0.0809	0.1065	17.45	18.71	20.08	21.5513	23.14	24.86	26.72	0.6811	0.1018	18.29	19.75	21.25	22.7793	24.34	25.94	27.57
15.50 – 15.99	0.0185	0.1079	17.75	19.08	20.51	22.0394	23.68	25.45	27.34	0.7679	0.1000	18.64	20.12	21.63	23.1590	24.72	26.29	27.90
16.00 – 16.49	0.1244	0.1091	18.07	19.47	20.96	22.5475	24.24	26.04	27.96	0.8558	0.0984	18.97	20.47	21.99	23.5289	25.08	26.65	28.22
16.50 – 16.99	0.2344	0.1101	18.40	19.87	21.42	23.0703	24.81	26.65	28.59	0.9445	0.0971	19.28	20.81	22.35	23.8908	25.44	26.99	28.55
17.00 – 17.49	0.3467	0.1109	18.74	20.28	21.90	23.6016	25.39	27.26	29.23	1.0342	0.0960	19.57	21.14	22.69	24.2461	25.80	27.34	28.89
17.50 – 17.99	0.4596	0.1117	19.07	20.68	22.37	24.1355	25.97	27.88	29.86	1.1246	0.0950	19.86	21.46	23.03	24.5995	26.15	27.69	29.22
18.00 – 18.49	0.5726	0.1124	19.39	21.09	22.85	24.6685	26.55	28.48	30.48	1.2152	0.0941	20.15	21.78	23.38	24.9545	26.51	28.05	29.56
18.50 – 18.99	0.6858	0.1131	19.71	21.49	23.32	25.2009	27.12	29.09	31.10	1.3059	0.0932	20.44	22.10	23.72	25.3105	26.87	28.40	29.91

M: median, L: Box-Cox power to remove skewness (L) S: Coefficient of variation

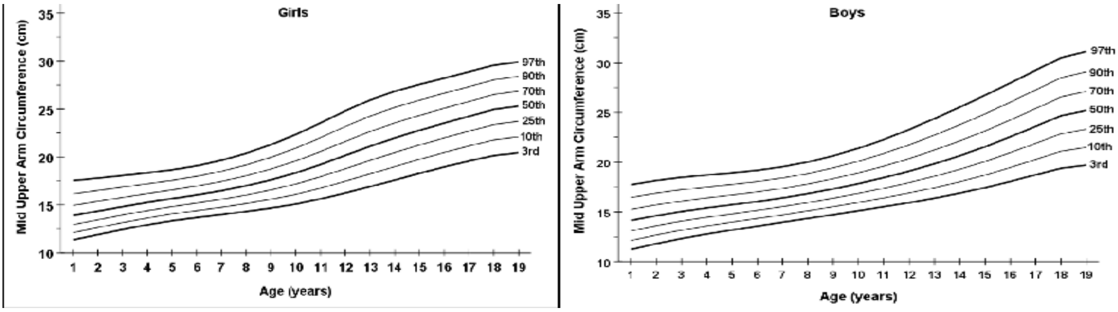

Figure 1: The centiles of mid upper arm circumference-for-age in Nigerian boys and girls.

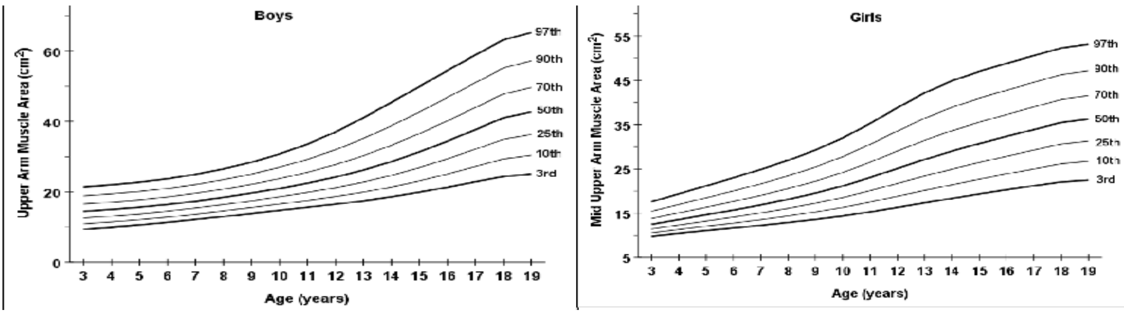

Figure 2: The centiles of mid upper arm muscle area-for-age in Nigerian boys and girls.

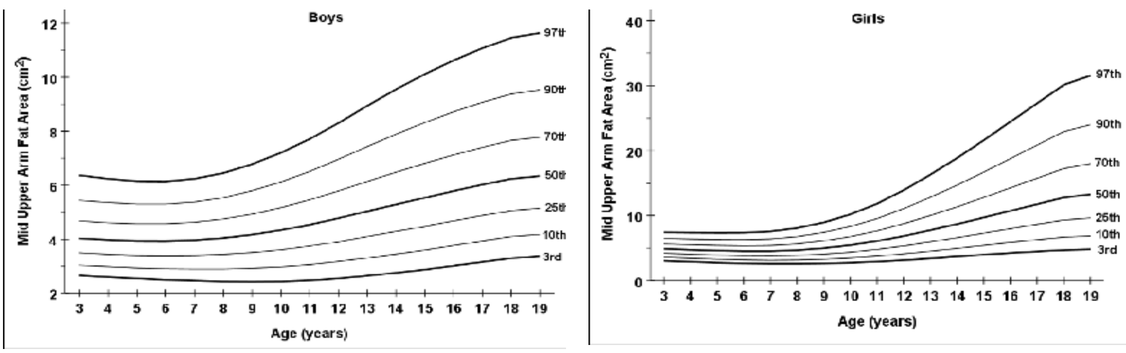

Figure 3: The centiles of mid upper arm fat area-for-age in Nigerian boys and girls

3rd, 10th, 25th, 50th, 70th, 90th and 97th percentiles for MUAC, UAMA and UAFA for both boys and girls. The tables also present the median (M), the Box-Cox power to remove skewness (L) and the coefficient of variation (S).

MUAC-for-Age

For both boys and girls, MUAC showed a steady increase with age. The distribution of MUAC by age for boys was positively skewed from age 1.5 – 15 years, as such, a negative power (L) is required to remove the skewness from the data (Table 1), whereas a positive power was used to remove skewness in other age categories. Still in Table 1, the distribution of MUAC for girls aged 10 years and below was positively skewed and a negative power was required to normalise the data, while the distribution for those aged 10.5 years and above was positively skewed and a negative power was used to restore normality of the data distribution. The LMS curve for boys was fitted with 3 edf for skewness, 4 edf for the coefficient of variation and the edf for the median curve was 6. For girls, the edf for skewness, coefficient of variation and median were respectively 3, 5 and 6. We noticed statistically significant differences in MUAC according to ages for both sexes. For boys, F = 4.425, P < 0.001, whereas for girls, F = 5.063, P < 0.001.

UAMA-for-Age

The distribution of UAMA by age was positively

Table 2: UAMA-for-age percentiles for boys and girls aged 2 – 18.5 years

	UAMA (cm²)																	
	Boys									Girls								
Age (years)	**L**	**S**	**3rd**	**10th**	**25th**	**50th (M)**	**70th**	**90th**	**97th**	**L**	**S**	**3rd**	**10th**	**25th**	**50th (M)**	**70th**	**90th**	**97th**
3.00 – 3.49	0.2205	0.2049	9.42	10.92	12.60	14.4707	16.56	18.87	21.42	-1.1619	0.1411	9.79	10.54	11.42	12.4915	13.80	15.45	17.58
3.50 – 3.99	0.1847	0.2012	9.70	11.19	12.86	14.7328	16.82	19.14	21.72	-1.0843	0.1454	10.12	10.93	11.88	13.0319	14.44	16.20	18.48
4.00 – 4.49	0.1489	0.1976	9.99	11.47	13.14	15.0072	17.10	19.43	22.03	-1.0068	0.1497	10.45	11.31	12.34	13.5705	15.08	16.96	19.38
4.50 – 4.99	0.1129	0.1940	10.29	11.77	13.44	15.3062	17.40	19.75	22.38	-0.9293	0.1540	10.76	11.69	12.79	14.1065	15.71	17.72	20.28
5.00 – 5.49	0.0771	0.1905	10.62	12.10	13.76	15.6352	17.74	20.11	22.76	-0.8522	0.1583	11.06	12.06	13.23	14.6423	16.35	18.48	21.18
5.50 – 5.99	0.0419	0.1873	10.97	12.45	14.12	16.0018	18.12	20.51	23.21	-0.7761	0.1627	11.36	12.42	13.68	15.1801	17.00	19.25	22.09
6.00 – 6.49	0.0076	0.1844	11.35	12.83	14.52	16.4152	18.56	20.99	23.72	-0.7012	0.1670	11.64	12.78	14.12	15.7185	17.65	20.02	23.00
6.50 – 6.99	-0.0255	0.1819	11.75	13.25	14.95	16.8741	19.05	21.52	24.32	-0.6282	0.1711	11.94	13.15	14.58	16.2765	18.32	20.82	23.93
7.00 – 7.49	-0.0574	0.1799	12.16	13.69	15.41	17.3681	19.59	22.11	24.99	-0.5565	0.1751	12.25	13.54	15.06	16.8619	19.02	21.65	24.89
7.50 – 7.99	-0.0881	0.1786	12.59	14.13	15.89	17.8888	20.16	22.76	25.71	-0.4858	0.1788	12.57	13.95	15.57	17.4792	19.76	22.52	25.89
8.00 – 8.49	-0.1178	0.1779	13.01	14.59	16.39	18.4381	20.78	23.45	26.52	-0.4166	0.1826	12.91	14.38	16.10	18.1298	20.54	23.43	26.94
8.50 – 8.99	-0.1473	0.1779	13.45	15.07	16.91	19.0220	21.44	24.22	27.41	-0.3498	0.1864	13.25	14.82	16.66	18.8135	21.36	24.40	28.05
9.00 – 9.49	-0.1761	0.1787	13.89	15.55	17.46	19.6435	22.16	25.06	28.41	-0.2860	0.1905	13.60	15.28	17.24	19.5321	22.23	25.43	29.24
9.50 – 9.99	-0.2029	0.1804	14.33	16.05	18.02	20.2980	22.93	25.97	29.52	-0.2264	0.1949	13.98	15.77	17.86	20.3060	23.17	26.54	30.54
10.00 – 10.49	-0.2259	0.1829	14.76	16.55	18.61	20.9832	23.75	26.97	30.74	-0.1723	0.1996	14.37	16.30	18.54	21.1463	24.19	27.77	31.98
10.50 – 10.99	-0.2438	0.1863	15.19	17.05	19.21	21.7066	24.62	28.05	32.08	-0.1254	0.2042	14.81	16.88	19.27	22.0591	25.31	29.10	33.55
11.00 – 11.49	-0.2559	0.1906	15.62	17.57	19.83	22.4763	25.57	29.23	33.56	-0.0862	0.2086	15.29	17.50	20.07	23.0412	26.50	30.53	35.24
11.50 – 11.99	-0.2618	0.1956	16.06	18.11	20.50	23.2994	26.60	30.52	35.20	-0.0524	0.2128	15.80	18.16	20.90	24.0690	27.75	32.03	37.01
12.00 – 12.49	-0.2609	0.2012	16.50	18.66	21.20	24.1883	27.73	31.94	37.00	-0.0218	0.2166	16.31	18.83	21.74	25.1115	29.02	33.55	38.81
12.50 – 12.99	-0.2523	0.2071	16.96	19.26	21.96	25.1562	28.95	33.49	38.96	0.0076	0.2199	16.83	19.49	22.57	26.1416	30.27	35.04	40.55
13.00 – 13.49	-0.2345	0.2129	17.47	19.91	22.79	26.2093	30.28	35.16	41.05	0.0380	0.2222	17.34	20.15	23.39	27.1394	31.46	36.44	42.17
13.50 – 13.99	-0.2061	0.2182	18.01	20.62	23.70	27.3497	31.70	36.92	43.21	0.0711	0.2234	17.84	20.79	24.19	28.0955	32.58	37.73	43.62
14.00 – 14.49	-0.1670	0.2229	18.59	21.38	24.68	28.5787	33.22	38.76	45.42	0.1074	0.2235	18.35	21.43	24.96	29.0108	33.63	38.90	44.89
14.50 – 14.99	-0.1175	0.2268	19.22	22.21	25.74	29.8989	34.83	40.68	47.65	0.1468	0.2227	18.85	22.06	25.72	29.8852	34.61	39.97	46.01
15.00 – 15.49	-0.0586	0.2299	19.89	23.11	26.88	31.3142	36.53	42.67	49.91	0.1887	0.2214	19.35	22.68	26.45	30.7229	35.54	40.95	47.00
15.50 – 15.99	0.0083	0.2323	20.60	24.07	28.11	32.8165	38.31	44.71	52.17	0.2326	0.2198	19.83	23.28	27.17	31.5346	36.42	41.87	47.93
16.00 – 16.49	0.0815	0.2339	21.34	25.07	29.39	34.3890	40.15	46.79	54.43	0.2777	0.2183	20.30	23.87	27.87	32.3325	37.29	42.78	48.82
16.50 – 16.99	0.1588	0.2349	22.10	26.12	30.73	36.0145	42.04	48.89	56.66	0.3237	0.2169	20.76	24.45	28.56	33.1221	38.15	43.67	49.70
17.00 – 17.49	0.2379	0.2353	22.87	27.19	32.11	37.6750	43.95	50.99	58.86	0.3707	0.2155	21.20	25.02	29.25	33.9041	39.00	44.55	50.57
17.50 – 17.99	0.3175	0.2354	23.63	28.27	33.50	39.3528	45.87	53.08	61.03	0.4179	0.2142	21.63	25.59	29.94	34.6835	39.84	45.42	51.43
18.00 – 18.49	0.3971	0.2353	24.37	29.35	34.90	41.0360	47.78	55.15	63.17	0.4653	0.2128	22.07	26.16	30.62	35.4638	40.69	46.29	52.29
18.50 – 18.99	0.4768	0.2351	25.08	30.42	36.30	42.7205	49.69	57.22	65.30	0.5128	0.2114	22.50	26.73	31.31	36.2442	41.53	47.16	53.15

M: median, L: Box-Cox power to remove skewness (L) S: Coefficient of variation

Table 3: UAFA-for-age percentiles for boys and girls aged 2 – 18.5 years

	UAFA (cm²)																
	Boys								Girls								
Age, y	L	S	3rd	10th	25th	50th (M)	70th	90th	97th	L	S	3rd	10th	25th	50th (M)	70th	90th	97th
3.00 – 3.49	-0.2002	0.2179	2.66	3.04	3.50	4.0346	4.68	5.44	6.37	0.2762	0.2220	3.04	3.59	4.20	4.8825	5.64	6.49	7.42
3.50 – 3.99	-0.1607	0.2183	2.63	3.01	3.47	4.0061	4.64	5.40	6.30	0.2639	0.2275	2.96	3.51	4.12	4.8102	5.58	6.44	7.39
4.00 – 4.49	-0.1214	0.2188	2.60	2.99	3.44	3.9793	4.61	5.36	6.24	0.2516	0.2331	2.89	3.43	4.05	4.7406	5.52	6.39	7.37
4.50 – 4.99	-0.0823	0.2194	2.57	2.96	3.42	3.9567	4.58	5.32	6.19	0.2394	0.2386	2.82	3.36	3.98	4.6759	5.47	6.35	7.35
5.00 – 5.49	-0.0433	0.2204	2.55	2.94	3.40	3.9406	4.57	5.30	6.15	0.2271	0.2442	2.75	3.29	3.91	4.6171	5.42	6.32	7.34
5.50 – 5.99	-0.0045	0.2220	2.52	2.93	3.39	3.9329	4.56	5.29	6.13	0.2150	0.2499	2.69	3.23	3.85	4.5651	5.38	6.30	7.34
6.00 – 6.49	0.0336	0.2243	2.50	2.91	3.39	3.9354	4.57	5.30	6.14	0.2031	0.2558	2.64	3.18	3.80	4.5255	5.35	6.29	7.36
6.50 – 6.99	0.0706	0.2276	2.49	2.90	3.39	3.9475	4.59	5.33	6.18	0.1918	0.2620	2.60	3.14	3.77	4.5082	5.35	6.32	7.43
7.00 – 7.49	0.1055	0.2317	2.47	2.90	3.40	3.9695	4.63	5.38	6.24	0.1813	0.2689	2.57	3.12	3.77	4.5226	5.40	6.40	7.56
7.50 – 7.99	0.1375	0.2366	2.45	2.90	3.41	4.0024	4.68	5.45	6.33	0.1720	0.2766	2.56	3.13	3.80	4.5776	5.49	6.55	7.77
8.00 – 8.49	0.1660	0.2424	2.44	2.90	3.44	4.0463	4.75	5.54	6.45	0.1643	0.2855	2.57	3.16	3.86	4.6792	5.64	6.77	8.08
8.50 – 8.99	0.1902	0.2489	2.43	2.91	3.47	4.1028	4.83	5.66	6.60	0.1582	0.2952	2.59	3.21	3.95	4.8205	5.85	7.06	8.48
9.00 – 9.49	0.2095	0.2556	2.43	2.93	3.51	4.1713	4.93	5.80	6.78	0.1539	0.3056	2.63	3.28	4.06	4.9969	6.11	7.42	8.96
9.50 – 9.99	0.2240	0.2623	2.43	2.95	3.56	4.2496	5.04	5.95	6.98	0.1508	0.3165	2.68	3.37	4.20	5.2095	6.41	7.84	9.54
10.00 – 10.49	0.2336	0.2689	2.44	2.98	3.61	4.3367	5.17	6.12	7.20	0.1487	0.3275	2.74	3.47	4.37	5.4584	6.77	8.33	10.20
10.50 – 10.99	0.2378	0.2754	2.46	3.02	3.67	4.4330	5.31	6.30	7.44	0.1468	0.3387	2.82	3.60	4.57	5.7488	7.18	8.90	10.97
11.00 – 11.49	0.2367	0.2819	2.48	3.06	3.75	4.5391	5.46	6.51	7.71	0.1447	0.3498	2.91	3.75	4.80	6.0827	7.65	9.55	11.84
11.50 – 11.99	0.2299	0.2879	2.51	3.11	3.83	4.6550	5.62	6.73	7.99	0.1419	0.3608	3.02	3.92	5.05	6.4564	8.18	10.28	12.83
12.00 – 12.49	0.2178	0.2934	2.55	3.18	3.91	4.7791	5.79	6.96	8.30	0.1381	0.3716	3.13	4.11	5.33	6.8645	8.76	11.09	13.93
12.50 – 12.99	0.2024	0.2983	2.60	3.24	4.01	4.9080	5.96	7.19	8.62	0.1338	0.3817	3.26	4.31	5.63	7.2995	9.38	11.94	15.10
13.00 – 13.49	0.1860	0.3026	2.65	3.31	4.10	5.0366	6.14	7.43	8.94	0.1302	0.3908	3.40	4.52	5.95	7.7518	10.02	12.83	16.32
13.50 – 13.99	0.1703	0.3063	2.70	3.38	4.19	5.1630	6.31	7.66	9.25	0.1280	0.3990	3.54	4.74	6.27	8.2195	10.68	13.75	17.57
14.00 – 14.49	0.1559	0.3093	2.76	3.45	4.29	5.2883	6.48	7.89	9.55	0.1271	0.4066	3.69	4.96	6.61	8.7040	11.36	14.70	18.87
14.50 – 14.99	0.1434	0.3117	2.82	3.53	4.38	5.4133	6.64	8.11	9.83	0.1275	0.4139	3.84	5.19	6.95	9.2033	12.07	15.69	20.22
15.00 – 15.49	0.1322	0.3133	2.88	3.60	4.48	5.5392	6.81	8.32	10.11	0.1291	0.4212	3.98	5.42	7.30	9.7122	12.80	16.70	21.61
15.50 – 15.99	0.1214	0.3141	2.95	3.69	4.58	5.6645	6.97	8.52	10.38	0.1322	0.4285	4.12	5.64	7.64	10.2257	13.54	17.74	23.03
16.00 – 16.49	0.1106	0.3141	3.02	3.77	4.68	5.7878	7.12	8.72	10.62	0.1369	0.4357	4.25	5.86	7.98	10.7388	14.28	18.78	24.46
16.50 – 16.99	0.1001	0.3136	3.09	3.85	4.78	5.9076	7.27	8.90	10.85	0.1427	0.4424	4.37	6.07	8.32	11.2496	15.02	19.82	25.89
17.00 – 17.49	0.0902	0.3127	3.16	3.94	4.88	6.0222	7.40	9.07	11.07	0.1495	0.4488	4.48	6.28	8.66	11.7587	15.76	20.86	27.30
17.50 – 17.99	0.0810	0.3117	3.23	4.02	4.97	6.1321	7.54	9.23	11.26	0.1569	0.4549	4.60	6.49	8.99	12.2678	16.50	21.90	28.71
18.00 – 18.49	0.0723	0.3105	3.30	4.10	5.06	6.2383	7.66	9.38	11.45	0.1646	0.4607	4.70	6.69	9.32	12.7779	17.24	22.94	30.13
18.50 – 18.99	0.0637	0.3092	3.38	4.18	5.15	6.3431	7.78	9.53	11.63	0.1724	0.4664	4.81	6.88	9.65	13.2888	17.99	23.99	31.56

M: median, L: Box-Cox power to remove skewness (L) S: Coefficient of variation

skewed for both boys and girls and a negative power was needed to remove the skewness from the data (Table 2). For both sexes, the LMS curves were modelled with 3 edf for L, 5 edf for median, M and 4 edf for the coefficient of variation, S. Because we couldn't collect TSFT for children younger than 3 years, the UAMA percentile curves were plotted from age 3 years and above. UAMA also showed a steady increase with age. Like with MUAC, statistically significant difference in UAMA

Table 4: Age- and sex-specific comparison of MUAC, UAMA and UAFA

	MUAC		UAMA		UAFA				
	Boys	Girls	Boys	Girls	Boys	Girls			
Age	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD	*P§*	*P†*	*P‡*
0.5	13.90 ± 1.73	13.61 ± 1.60	-	-	-	-	0.530	-	-
1.0	14.04 ± 1.52	13.65 ± 0.90	-	-	-	-	0.430	-	-
1.5	14.57 ± 0.82	14.36 ± 1.82	-	-	-	-	0.348	-	-
2.0	15.65 ± 0.94	14.64 ± 1.99	-	-	-	-	0.287	-	-
2.5	15.13 ± 1.19	14.76 ± 1.39	-	-	-	-	0.069	-	-
3.0	15.42 ± 1.88	14.80 ± 0.97	14.43 ± 2.63	13.01 ± 1.37	4.10 ± 1.29	5.74 ± 1.12	0.088	0.376	0.178
3.5	15.90 ± 1.68	15.85 ± 1.62	15.81 ± 3.44	13.05 ± 1.00	4.15 ± 0.99	5.89 ± 1.14	0.704	0.159	0.085
4.0	15.93 ± 1.27	15.90 ± 1.49	16.14 ± 3.01	13.92 ± 4.20	4.16 ± 1.23	4.38 ± 2.12	0.531	0.169	0.681
4.5	16.95 ± 1.61	16.52 ± 1.36	16.21 ± 2.75	14.39 ± 2.33	4.17 ± 0.30	4.41 ± 0.98	0.555	0.130	**0.019**
5.0	16.96 ± 1.41	16.63 ± 0.96	16.33 ± 3.34	15.24 ± 1.80	4.21 ± 0.96	4.44 ± 1.21	0.118	0.632	**<0.001**
5.5	16.97 ± 1.46	16.72 ± 1.20	16.42 ± 2.75	15.39 ± 2.94	4.23 ± 0.91	4.50 ± 1.20	0.161	0.215	**<0.001**
6.0	16.99 ± 1.37	16.86 ± 1.38	16.53 ± 3.16	15.83 ± 2.99	4.25 ± 0.86	4.56 ± 1.20	0.813	0.089	**<0.001**
6.5	17.52 ± 1.39	16.98 ± 1.25	17.25 ± 3.28	16.60 ± 2.63	4.27 ± 0.83	4.61 ± 1.21	0.865	0.194	**0.003**
7.0	17.56 ± 1.37	17.28 ± 1.59	17.95 ± 3.26	17.40 ± 3.84	4.30 ± 1.08	4.67 ± 1.26	0.923	0.257	**<0.001**
7.5	17.74 ± 1.31	17.37 ± 1.50	18.25 ± 3.18	17.99 ± 3.58	4.33 ± 0.87	4.78 ± 0.89	0.735	0.592	**<0.001**
8.0	17.86 ± 1.37	17.42 ± 1.44	18.72 ± 3.31	18.29 ± 3.08	4.36 ± 0.78	4.94 ± 1.42	0.362	0.302	**<0.001**
8.5	17.90 ± 1.44	17.57 ± 1.75	18.97 ± 3.56	18.34 ± 4.06	4.37 ± 1.10	5.43 ± 1.53	0.613	0.422	**<0.001**
9.0	17.94 ± 1.38	17.68 ± 1.45	19.99 ± 3.31	19.36 ± 3.20	4.39 ± 1.25	5.53 ± 1.62	0.758	0.074	**<0.001**
9.5	17.96 ± 1.53	18.10 ± 1.56	21.07 ± 4.09	20.66 ± 3.84	4.40 ± 1.13	5.61 ± 1.71	0.137	0.387	**<0.001**
10.0	17.98 ± 1.52	18.86 ± 2.03	21.32 ± 3.87	21.31 ± 4.82	4.44 ± 1.19	5.63 ± 1.89	**0.014**	0.534	**<0.001**
10.5	18.06 ± 1.74	18.92 ± 1.90	22.21 ± 4.58	21.69 ± 4.33	4.57 ± 1.06	5.89 ± 2.11	**0.001**	0.314	**<0.001**
11.0	18.59 ± 1.61	19.19 ± 1.92	23.10 ± 4.15	23.26 ± 4.76	4.60 ± 1.36	6.35 ± 2.05	**0.003**	0.756	**<0.001**
11.5	18.88 ± 1.61	19.82 ± 1.77	23.80 ± 4.34	23.83 ± 4.78	4.76 ± 1.49	6.67 ± 1.84	**<0.001**	0.063	**<0.001**
12.0	19.09 ± 1.72	20.27 ± 2.11	24.40 ± 4.67	24.44 ± 5.36	4.82 ± 1.32	7.11 ± 2.96	**<0.001**	0.627	**<0.001**
12.5	19.64 ± 1.98	21.06 ± 2.35	25.72 ± 5.53	25.74 ± 6.60	5.28 ± 1.60	8.30 ± 3.23	**<0.001**	0.511	**<0.001**
13.0	20.11 ± 2.32	21.46 ± 2.65	27.20 ± 7.12	27.32 ± 7.36	5.31 ± 1.71	8.44 ± 3.84	**<0.001**	0.067	**<0.001**
13.5	20.43 ± 2.14	21.40 ± 2.22	28.29 ± 6.67	28.39 ± 6.50	5.38 ± 1.53	8.54 ± 3.32	**<0.001**	0.896	**<0.001**
14.0	21.05 ± 2.48	22.03 ± 2.57	29.08 ± 7.77	29.11 ± 7.24	5.46 ± 1.95	9.08 ± 3.62	**<0.001**	0.997	**<0.001**
14.5	20.76 ± 2.09	22.62 ± 2.32	31.64 ± 6.63	29.72 ± 7.41	5.51 ± 1.57	9.89 ± 3.73	**<0.001**	**0.027**	**<0.001**
15.0	21.48 ± 2.25	22.79 ± 2.13	32.24 ± 7.23	30.38 ± 6.37	5.69 ± 2.00	10.31 ± 4.01	**<0.001**	**<0.005**	**<0.001**
15.5	22.34 ± 2.78	23.17 ± 2.01	34.37 ± 9.07	31.46 ± 6.36	5.76 ± 1.96	11.57 ± 4.89	**0.007**	**0.003**	**<0.001**
16.0	22.50 ± 2.56	23.48 ± 2.33	34.90 ± 8.72	32.06 ± 6.13	5.88 ± 1.84	12.12 ± 5.73	**0.003**	**<0.005**	**<0.001**
16.5	23.24 ± 2.47	24.28 ± 2.09	36.88 ± 8.17	32.98 ± 7.39	6.58 ± 2.03	12.21 ± 5.30	**0.001**	**<0.001**	**<0.001**
17.0	23.54 ± 2.96	24.89 ± 2.43	40.21 ± 9.80	33.55 ± 8.12	6.61 ± 1.73	12.25 ± 6.12	**0.003**	**<0.001**	**<0.001**
17.5	23.89 ± 2.28	25.04 ± 1.88	42.25 ± 7.19	33.90 ± 7.08	6.70 ± 2.13	12.77 ± 5.70	**0.004**	**<0.001**	**<0.001**
18.0	24.04 ± 2.39	25.02 ± 2.57	43.76 ± 8.59	36.13 ± 7.33	6.82 ± 1.75	13.50 ± 5.25	**<0.001**	**<0.001**	**<0.001**
18.5	24.45 ± 2.29	25.63 ± 2.82	44.38 ± 8.42	36.82 ± 8.32	6.96 ± 1.42	16.71 ± 3.83	**<0.001**	**0.009**	**<0.001**

§: P-value for comparison of MUAC between boys and girls: †: P-value for comparison of UAMA between boys and girls; ‡: P-value for comparison of UAFA between boys and girls: No UAMA and UAFA was recorded for children less than 2 years old because triceps skinfold was not collected for these age groups; MUAC; mid-upper arm circumference, UAFA; upper arm fat area, UAMA; upper arm muscle area

according to age for both sexes; for boys, F = 3.563, P < 0.001, while F = 2.949, P < 0.001 for girls.

UAFA-for-Age

For UAFA, the curves were modelled on the original age scale like UAMA with edf 3 for the skewness, edf 5 for the median and edf 4 for the coefficient of variation for both sexes. Compared to boys, girls consistently have higher UAFA at all ages, as expected. However, the age increment in UAFA was slow, irrespective of sex. A significant age-specific difference in UAFA for both sexes was observed: F = 1.452, P < 0.001 for boys and F = 2.115, P < 0.001 for girls.

Comparison of Centile Curves

Figure 4 shows 3rd, 50th and 97th centiles of MUAC by sex, age and region; Nigeria and the US (international reference) from 1 to 19 years. The US curves are shown as dotted lines, whereas the Nigerian curves are shown as solid lines, and it is obvious that the US curves used for comparisons do not track neatly to the Nigerian curves for both boys and girls. However, for both sexes, the US curves are shown to be appreciably higher than Nigeria's across all ages and all centiles considered. The 3rd centile curves for both sexes were found to be below the 3rd centile of the US reference data, while the median and 97th percentiles of MUAC for boys were found to consistently diverge from age 2 to 19 years. At ages ~15 and 16 years, the 97th centile curve for Nigerian boys intersects with the median of the US reference data. A comparison of the median curves of Nigerian girls to their US counterparts indicates that the median curve of Nigerian girls was also found to be below that of the US. Still, for girls, the 97th centile curve diverged from early life to 19 years, similar to that of Nigerian boys. However, the 97th centile of Nigerian girls did not intersect with the US median curve, as seen in boys.

Mid Upper Arm Muscle Area

Figure 5 gives the 3rd, median and 97th centiles by age, sex and region. In comparison to US reference data, the UAMA curves of Nigerian boys and girls are similar in terms of age trends and rankings. The median and 97th UAMA curves of Nigerian boys and the US reference data intersect at age 3 years and appreciably begin to diverge at age 4 years. Further divergence between the two curves for the three centiles was noticed at age 12. Note that the 3rd centile of the reference curve further diverges until it is slightly below the median UAMA of Nigerian boys at ages ~15 to 19 years. Comparison of the female centile curves to the reference data indicates that the two centile curves are much closer together, although the western centiles are relatively higher across most ages. The 3rd centiles intersect at 3 to 10 years while the median intersects at ages 17 and 19 years. The 97th centile of the West is higher compared to that of Nigeria from ages 2 to 15; they intersect at ages 18 and 19.

Mid Upper Arm Fat Area

Figure 6 gives the 3rd, median and 97th centiles of UAFA by age, sex and region. Note that the 3rd and median centiles are similar and much closer to each other in terms of age trends and rankings for both sexes. In early life, the median curve of boys and 3rd centile of the reference data overlapped, then slightly diverged and remained relatively close to each other. The 97th centile of boys and the median of the reference track are relatively close to each other across all ages but for ages 9 to 13 years. In contrast, the 97th centile curve of the West rose steeply across all ages in both boys and girls. The pattern of 3rd and median curves for girls is slightly similar to that of boys. However, the 97th centile for girls diverged appreciably higher from age 7 to 18 years. The Western reference of UAFA is relatively higher in girls than boys at 97th. The reasons for the marginal difference between the 97th percentiles for the reference and Nigerian children are unexplained, but it is less likely to be related to smoothing.

Results for the comparison of age- and sex-specific MUAC, UAMA and UAFA were presented in Table 4. From the table, there is a gradual increase in MUAC and its derivatives with age. The results showed that before age 10 years, MUAC was independent of the sex and age of the child. Nevertheless, boys were seen to have higher MUAC from 0.5 to 9 years. At age 10 and above, the MUAC of girls was significantly higher than that of boys. In respect to UAMA, boys exhibit higher UAMA than girls. However, this difference in UAMA was not significant before age 14.5 years. From age 14.5 years, we noticed significant sex dependence in UAMA. UAFA on the other hand, indicates significant sex dependence from age 4.5 years with a proclivity towards girls.

DISCUSSION

The main contribution of this cross-sectional study

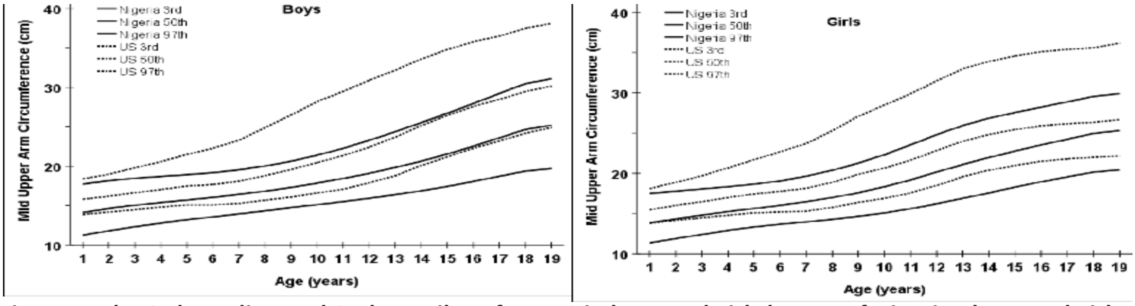

Figure 4: The 3rd, median and 97th centiles of MUAC in boys and girls by age of Nigerian boys and girls (solid lines) with US reference data (dotted lines).

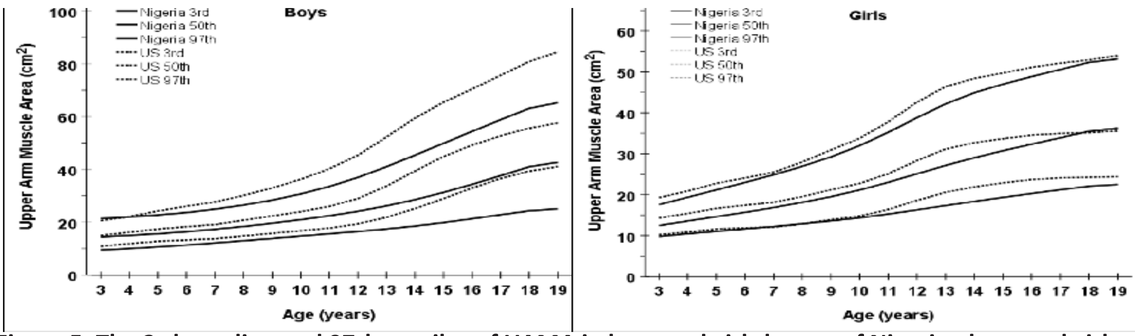

Figure 5: The 3rd, median and 97th centiles of UAMA in boys and girls by age of Nigerian boys and girls (solid lines) with US reference data (dotted lines).

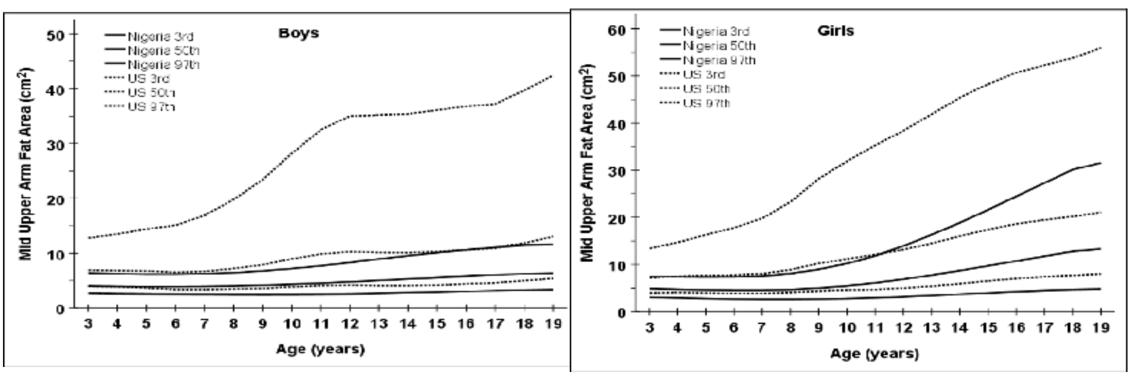

Figure 6: The 3rd, median and 97th centiles of UAFA in boys and girls by age of Nigerian boys and girls (solid lines) with US reference data (dotted lines).

to the current literature is that it is the first study that constructs smoothed reference percentile curves for MUAC and its derivatives, UAMA and UAFA for Nigerian children and adolescents by age and sex. The three parameters for calculating z-scores are also presented for the three reference percentiles for each age and sex. Representative samples for the reference curves were collected from children and adolescents attending crèche, nursery, primary, junior and senior secondary schools in Lafia and Doma local government areas (LGAs) of Nasarawa State, Nigeria. Lafia LGA was considered an urban setting, whereas Doma was considered rural. Two anthropometric indicators of SAM are MUAC and WHZ. The WHO and United Nations International Children's Emergency Funds (UNICEF) recommend the use of WHZ <- 3 (severely low WHZ) and MUAC < 115 mm (severely low MUAC) as cut-off values to guide admission of children with SAM to feeding programmes or further medical investigation. Whereas WHZ is a statistical expression that uses weight as several z-scores or standard deviations below and above the reference median value for a particular stature, MUAC on the other hand, is an absolute value [25]. Compared to WHZ, MUAC is judged to be a simple, inexpensive tool that requires a single measurement for diagnosing malnutrition and has the potential to identify children at risk of mortality [26]. Albeit it's not clear which of these two indicators is a better predictor of children's elevated mortality risks [27,28], the use of absolute MUAC or in conjunction with WHZ as a screening tool by field organisations to screen vulnerable children in need of intervention is becoming ubiquitous [29]. However, earlier studies have reported a poor association between the use of MUAC and WHZ as malnutrition diagnostic tools for SAM [7]. For instance, Berkley et al. (2005) reported that 65.1% of children hospitalised after initially being diagnosed as having WHZ < -3 were also identified as having MUAC < 115 mm, while 56% of the SAM cases based on MUAC were also found to have WHZ < -3 [30]. Furthermore, studies by Fernandez and colleagues reported that in a study of 34 937 children aged 6 – 59 months, 75% of the children in the study with WHZ < -3 were also found to have MUAC < 115 mm [31].

From the foregoing, adopting a single approach for identifying and classifying children with SAM in children (especially those < 5 years) may not be suitable and may be marred with misclassification due to other extraneous variables such as age, sex and stunting, which frequently affect SAM children. Furthermore, such nonalignment between indicators poses significant intervention confusion and challenges because being fine-grained on one of these indicators may under-detect the true level of acute malnutrition, thereby resulting in missed opportunities for intervention and treatment. Also, adopting an approach to diagnosing SAM based on either indicator can lead to undue inflation of the intervention programme due to uncertainty on whether or not children identified by one indicator and not by the other truly require robust nutritional rehabilitation.

A significant puzzle in public health nutrition is the potential for the identification and application of the most sensitive marker of undernutrition to reduce the risk of mortality. MUAC can serve as an alternate means of assessing nutritional status when routine anthropometric indicators of nutrition (weight, height and BMI) are difficult to come by [32]. For this reason, MUAC measures in the present study will provide an alternative for monitoring, evaluation and management of nutritional status in Nigeria and other sub-Saharan countries that share a common sociodemographic background with Nigeria. Because the LMS coefficients provided herein are age- and sex-specific for a child or adolescents, it is possible to compute z-scores for each of the three measures; MUAC, UAMA or UAFA.

Because there are no previously established centile patterns of MUAC, UAMA and UAFA in Nigeria, the reference ranges presented in the present study could not be compared to any local data. Therefore, the reference ranges in the present article will serve as a reference guide to future studies. However, a comparison of the reference ranges presented in the current study with previous studies revealed that the pattern of age change in MUAC, UAMA and UAFA from childhood to adolescents differs in both sexes [16]. Intriguingly, it is observed that the 97th centiles of UAFA increased steeply as seen in Figure 6, comparing the Nigerian children and adolescents with contemporaneous US reference data. MUAC has been used as a good alternative indicator of nutritional status especially during routine nutritional assessment and can be used as proxy for low weight-for-height (wasting) [34]. Although comparisons of these two indicators show that they are poorly associated [35,36], there appears to be a consensus that low MUAC is a superior predictor of mortality than WHZ [10,11,37].

We evaluated age- and sex-specific differences in MUAC, UAMA and UAFA. Regarding MUAC, there is no significant difference in MUAC prior to 10 years. For much of early life, boys are relatively having higher MUAC compared to girls. As MUAC continues to increase with age, girls experienced significant MUAC rebound at age 10 years. One possible proposition is that MUAC is age- and sex independent in early life but indicates sex-dependent later in life (age 10 and above as seen in the current study) especially at puberty. For the most part, we noticed difference in UAMA based on age and sex. The difference based on sex was appreciably in favour of boys than girls and the difference was not significant prior to age 14 years. It stands to reason, therefore, that UAMA was sex independent from early life to age 14 years while it indicates sex dependence from pubertal age and beyond. Results for UAFA indicate significant difference from age 4.5 years and the sex difference was consistently in favour of girls. Our findings on UAMA and UAFA were in congruent to that of Oyhenart [14]. This is due to sexual dimorphism that exists in body composition with girls having relatively more fat mass and boys more muscle. Women have been reported to have ~ 10% higher body adiposity than men [38,39].

Comparison of MUAC-for-age of Nigerian boys and girl to that of the West showed that undernutrition prevailed in children and adolescents in our study compared to those in the US. The low MUAC-for-age of the surveyed Nigerian children and adolescents compared to those in the West indicates remarkable undernutrition. The prevalence of undernutrition among Nigerian children and adolescents has not been investigated recently.

Although the factors underlying the low MUAC-for-age of the present study have not been investigated, the difference in genetic make-up, epigenetics, socioeconomic and demographic status may partly be responsible. Other plausible and relevant factors that might have exacerbated the nutritional status of children and adolescents in our study compared to the US reference data include poor; health care system, sanitation, low literacy level, diet and lifestyle.

The economic growth of Nigeria in 2018 and 2019, being the intervening period of the present study may have played a role in the low MUAC-for-age (being an alternative indicator of nutritional status). The gross domestic product of Nigeria in 2018 and 2019 is 1.91% and 2.27% with per capita income of $2,032.73 and $2,229.859, respectively [40,41]. This is coupled with a frightening 23.1% unemployment rate, 20.21% underemployment rate, combined unemployment and underemployment rate 43.3% (National Bureau of statistics), farmers' inability to farm due to escalated insecurity either in the form of banditry or farmers-herders' conflict and surge in prices of essential goods. Against this, is low standard of living the subjects were exposed to. Consequently, Nigeria's low economic growth has led to changes in diet and lifestyle. Children now eat low diet food, spend more time after school performing menial jobs (either in the farms or engaged as artisan) to support family. Watching TV, playing computer games, living in good houses and reliance on transport system are now seen as luxury and for the well-off.

The new centile ranges for upper arm measures provide a description of the prevailing upper arm status of healthy Nigerian children and adolescents. To our knowledge, the present article is the first in Nigeria to construct centile curve of upper arm measures. Notwithstanding, these curves were fitted based on data from Nigerian children and adolescents, we hope that they can as well be of immense use not only in Nigeria, but in other sub-Saharan countries with similar sociodemographic backgrounds like Nigeria.

Our study has some limitations. One of such limitations is the limited number of study participants per age and our inability to measure the skinfold of some age groups. Such sample size limitation weakens statistical power of the results especially at extreme ages. Data were collected from schools and clinics, thereby excluding out-of-schoolchildren, those absent from school in the day of data collection, or those in internally displaced persons' camps. Also, permission was not granted for data collection from some schools recruited ab initio. We did not account for the impact of sociodemographic factors on nutritional status.

Future research should consider other states in Nigeria or at least geopolitical zones and should account for the impact of sociodemographic factors (including but not limited to level of unemployment/underemployment,food shortage) on nutritional status. Furthermore, such studies should be backed with larger sample size across each age category including extremes. The Nigerian government should conduct a national nutritional assessment survey with a view to better understand the nutritional status of children and adolescents and to identify those in need of intervention. Such study or any other future studies should define cut-off points for assessing SAM and should account for Nigerian peculiarities.

CONCLUSION

The new reference centile ranges for MUAC, UAMA and UAFA we documented from this study provide a handy tool for assessing nutritional status under various conditions. Because there are no previous studies in Nigeria that have established centile patterns of MUAC, UAMA and UAFA, these up-to-date centile curves will provide the basis for further comparisons in future studies. Results from this study can also be used for comparison to other parts of Nigeria. The rate of undernutrition in Nigeria is on the increase. This study also revealed that, relative to US reference ranges, the MUAC, muscle area and fat area of Nigerian children and adolescents consistently fall below that of their counterparts in the US, an indication of low nutritional status. This has significant implications that require addressing the underlying aetiology of undernutrition and for the current and future health of Nigerian children and adolescents.

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