Journal of Anatomical Sciences

Email:anatomicaljournal@gmail.com

J Anat Sci 12 (2)

Reference Ranges for Skinfold Thicknesses in Nigerian Children and Adolescents Aged 3 – 19 years

[1*]Nwankwo M, [2]Danborno B, [2]Musa SA and [3]Abubakar AS

[1]Department of Anatomy, College of Medicine, Federal University Lafia-Nigeria
[2]Department of Anatomy, College of Medical Sciences, Ahmadu Bello University
Zaria-Nigeria
[3]Department of Medical Laboratory Science, College of Medical Sciences, Ahmadu Bello University Teaching Hospital, Zaria

Corresponding author: Nwankwo M
E-mail: nmonday65@gmail.com; +2348065712691

ABSTRACT

Skinfold measurements have long been considered as a valid anthropometric indicator of subcutaneous fat. Nonetheless, percentile ranges for population-based skinfold thicknesses for Nigerian children and adolescents are not available. The present study developed new age- and sex-specific percentile reference curves for biceps, triceps, subscapular and suprailiac skinfold thicknesses in a representative sample of healthy Nigerian children and adolescents. The sample comprised 3,413 boys and 3,496 girls aged 3 – 19 years, randomly selected from rural and urban communities in Nasarawa State, Nigeria. The LMS method was used to fit percentile curves for biceps, triceps, subscapular and suprailiac skinfold thicknesses and the LMS parameters were generated for calculating standardized Z-scores. Subjects were classified as being underweight or having normal weight based on their BMI values using the WHO 2007 reference. The new reference percentile ranges for biceps, triceps, subscapular and suprailiac skinfold established age- and sex-specific of subcutaneous fat distribution. Comparison of centile curves of the underweight and normal weight children indicate higher subcutaneous adiposity in subjects with normal weight than the underweight. The present study has for the first time presented age- and sex-specific skinfold percentiles and parameters for calculating standardized Z-scores of Nigerian children and adolescents. The tabulated percentiles and Z-scores can be useful indicator of subcutaneous fat and local reference for anthropological studies.

Keywords: Skinfold, percentile curve, Z-scores, underweight, children

INTRODUCTION

As malnutrition in all its forms continues to threatened the world as the leading cause of poor health and death, Nigeria is one of the six countries that account to half of global child death from malnutrition [1] and is a direct or underlying cause of 45% of all death of under-five children [2]. Skinfold is a fold of skin formed by pinching or compressing 2 layers of the skin and its underlying subcutaneous layers in order to measure fat in specific part of the body. Skinfold has long been used as a measure of nutritional status [3-5]. Skinfold thicknesses evaluation are inexpensive, non-invasive and simple anthropometric technique for assessing body composition, body somatotype and nutritional status [4,6-11]. Because of the likely striking inequalities in anthropometrics due to genetic, demographic, sex, age, socioeconomic status and cultural divide and for the purpose of comparison, it is important to develop reference values.

Abnormal accumulation of subcutaneous adipose tissue assessed with skinfold thicknesses has been found to be related to dyslipidaemia which increased the risk of atherosclerosis, coronary heart disease, metabolic syndrome, stroke and hypertension [9, 12, 13]. In 2007, the World Health Organization published growth reference curves for anthropometric measurements including triceps and subscapular skinfolds were collected from Brazil, Ghana, India, Norway, Oman and the USA [14]. Such international reference values are of immense advantage in that they allow for cross-national comparisons, although it is not clear how well they fit children and adolescent populations whose data were not included in the reference population. In addition to skinfold data of Nigerian children and adolescents not included in generating the reference curves, to our knowledge, Nigeria has no national reference data generated from the six geopolitical zones. Despite being recommended for use by countries around the world [15], the published reference data by the

WHO may not have accounted for the peculiarities (demographic settings, genetics, culture and socioeconomic inequities) in Nigeria and therefore, making it non-applicable to Nigeria. It is expected that variabilities may exist at subnational levels (geopolitical zones and across states within and between these zones).

Some countries have developed their reference values from national studies [2, 16, 17]. In Nigeria, to our knowledge, there is no national reference values for skinfold thicknesses for children and adolescents. The few available studies in which skinfold were measured were not rigorous and robust enough and are flawed in many respects especially in their methodological design such as sampling method, for instance use of non-representative data from regions, heterogeneity of measurement techniques and sampling and poor statistical power in some age categories [18-20].

Because of the inherent use of skinfold thickness as a nutritional status screening indicator, absence of established national reference for Nigerian population and the need to fill the gap in knowledge, herein, we aimed to generate reference percentiles for biceps, triceps, subscapular and suprailiac skinfold thicknesses for Nigeria children and adolescents. In order to allow for the possibility to calculate the corresponding age and sex-specific standardized *Z*-scores (standard deviation from the mean), LMS parameters from the transformed data were provided. The secondary objective of this study is to compare these reference percentiles to that of individuals identified as underweight defined by 2007 WHO recommended body mass index (BMI)-for-age cut-off points to learn more on the potential differences in skinfold thicknesses based on nutritional status.

MATERIALS AND METHODS

Communities and participants: The study was conducted in rural and urban communities of Nasarawa State, Nigeria. Nigeria is divided into six geopolitical regions – northeast, northwest, northcentral, southeast, south-south and southwest. This region is located in northcentral geopolitical region. The study was conducted in two local governments areas (LGAs), Lafia (being the state capital) and Doma (24 km from Lafia). The urban samples were collected from Lafia while the rural samples were collected from Doma. Samples were collected from preschool, nursery, primary and secondary (junior and senior) schools. The rural samples display homogenous ethnic (primarily Alago, Eggon and Tiv), cultural, sociodemographics and economic attributes. Agriculture is the mainstay of Doma and Lafia and the entire State's economy with the production of cash crops. The State is also rich in solid minerals such as baryte, bauxite and salt, although these resources are being mined at the moment by artisanal miners. The major means of livelihood of most parents in Doma is farming and trading. The urban samples are predominantly Hausa, Bare-Bari, Alago, Eggon, Migili, Fulani and Gwandara. Although the urban sample are rather more ethnic diversity, they display similar cultural and sociodemographics when compared to the rural sample. Lafia has a much larger (pop. 330,712) population and higher socioeconomic status than Doma (pop. 139,607). Parents of most of the participants in Lafia are traders or agriculturalists. Others are civil servants, artisans with few professionals. All of the participants both in Lafia and Doma attended school.

School-aged children and adolescents aged 3 – 19 years were recruited in the study. Before participation in the study subject must be free from: chronic disease that might affect growth (such as anaemia-related, renal, cardiac diseases, etc.) and absence of psychological or physical disability. Additionally, because of the low prevalence of overweight in our sample, which is reflected in the small number of overweight and no obesity, these subjects were excluded from the analytic population. Subjects were randomly selected using two-stage sampling technique. All schools (public and private) were sampled and stratified by urban/rural setting. In the second stage, all children and adolescents within the required age group within the sampled schools make up the sampling frame. Selection of children and adolescents for the survey was by stratified random sampling, the stratification variables being classes.

Anthropometric data: Anthropometric measurements were taken as per standard procedures detailed by the International Society for Advancement of Kineanthropometry (ISAK) protocol [21] and were taken with Harpenden Skinfold Calliper (graduation 0.2 mm, range 80 mm, model: HSB-BI). All anthropometric measurements were taken by designated researcher throughout the study period. Weight, height and four skinfolds (biceps, triceps, subscapular and suprailiac) were measured for all participants. Height was measured in centimetres using a portable stadiometer with the subjects standing in upright position on flat ground without shoes and head in horizontal Frankfurt plane. Similarly, weight was also measured without shoes in light clothing and was measured in kilograms using a portable weighing scale, FitScan BC-585F, (TANITA Corporation, Tokyo, japan) placed on a level ground.

All skinfolds were measured to the nearest 1 mm with the subject in an upright position. The skinfold thickness for each site was pinched to raise two layers of skin and the subcutaneous adiposity excluding the muscle. Bicep skinfold was measured in front side of middle upper arm, triceps skinfold was picked up at the posterior midline of the left arm, over the triceps muscle, at the lower margin of the olecranon process of the ulna with the subject's arm at his/her side, subscapular skinfold was measured on the left side, just below the inferior angle the shoulder blade whereas suprailiac (otherwise known as iliocristale) skinfold was measured above the ilium of the hip bone.

Body mass index (BMI = weight (kg)/height $(m)^2$) was derived and converted to Z-scores using the SPSS macro based on the WHO 2007 growth reference. BMI z-scores (BAZ) were categorised into dichotomous variables as normal weight and underweight by collapsing BMI z-scores < -2 (thinness) and < -3 (severe thinness) into total underweight and all others as normal weight. This is because of the relatively small size of those classified as overweight (BAZ > +1) and obese (BAZ > +2), and those with BAZ exceeding 3 in absolute value were automatically excluded (flagged) as outliers from the final dataset.

Reliability/Quality control: After initial training, data for intra-observer reliability were collected on two consecutive days by performing a measurement reliability study. Measurements of 50 children from the first school visited by individual research assistants for the selected variables were made. The minimum acceptable intraclass correlation coefficient [22] between any pair of trained raters of these measurements was set as R = 0.97. Note that "R" is defined as the proportion of the variance of an observation as a result of between subject variance in an error free score [23].

Ages: To determine chronological (decimal) age, participants were asked to enter date of birth as recorded in their birth certificate. Those without birth certificate were asked to inquire from their parents. For children in nursery or primary schools, date of birth was recorded by their parents or caregiver. To calculate chronological age of each child, SPSS date and time wizard was used to calculate the difference between date of birth and date of investigation (expressed in months).

Participants/Ethical Clearance: Ethical approval was received from Ahmadu Bello University, Zaria Research Ethics Board. Permission was also obtained from authorities of participating schools while participants (parents) received consent form outlining the study protocol. Only those who provided signed informed consent to participate in the study were included.

Statistical analyses: Data for 3,413 boys and 3,496 girls aged 3 – 19 years from Lafia and Doma LGAs collected between 2018 – 2019 were used to produce age- and sex-specific centiles of four skinfolds. The data were analysed by the LMS method [24] to generate smoothed percentile values and curves fitted for each sex across age for each skinfold. Natural cubic splines were fitted by maximum penalized likelihood [25] to create three smoothed curves across each age *t*: L(*t*) representing the Box-Cox power; M(*t*), the median and S(*t*), the coefficient of variation. At each stage of modelling, raw data for each skinfold and sex was used to generate the smoothed percentiles and their corresponding L, M and S parameters across age category. Percentile curves at age t were then computed as:

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

Z_α = denotes the normal equivalent deviation for tail area α, $P_{100\alpha}(t)$ represents the percentile equivalent to Z_α. The reciprocal of the equation above expresses any given skinfold thickness as a Z-score:

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

Where the values for L, M and S are specific for the child's age, sex and skinfold thickness.

Equivalent degree of freedom (edf) measures the complexity of each fitted curve and the following edf were chosen to model the smoothed L, M and S for each sex and skinfold thickness: 1, 5 and 2 for biceps skinfold thickness in boys; 1, 5 and 3 for biceps skinfold thickness in girls; 1, 6 and 3 for triceps skinfold thickness in boys; 1, 8 and 3 for triceps skinfold thickness in girls; 1, 3 and 2 for subscapular skinfold thickness in boys; 1, 5 and 3 for subscapular skinfold thickness in girls; 1, 4 and 2 for suprailiac skinfold thickness in boys; 1, 3 and 2 for suprailiac skinfold thickness in girls respectively. Global goodness-of-fit of the final model was assessed with worm plots and Q tests [26,27].

For each skinfold thickness, seven fitted percentiles of 3rd, 10th, 25th, 50th, 75th, 90th and 97th were computed within 6 months age units from 3.00 to 19.49 years. Individuals with BMIZ < -2 and < -3 were categorised as underweight using the 2007 WHO growth reference data. This was done using the WHO SPSS macro (for Windows). Because the 2007 WHO growth reference data was for children and adolescents 5 – 19 years old, this is the age group whose nutritional status was defined using the reference data. The LMS smoothing algorithms similar to the population curves was used to fit smoothed percentiles for individuals identified as underweight across ages for comparison. LMSchartmaker Pro version 2.54 program (Medical Research Council, London, UK, 2011) was used to fit the smoothed percentiles. All other statistical analyses were performed with Statistical Package for Social Sciences (IBM SPSS, Illinois, Chicago, USA) version 26.

RESULTS

The smoothed age- and sex-specific percentiles and their corresponding LMS parameters for biceps, triceps, subscapular and suprailiac skinfold thicknesses are presented in Tables 1 – 4 and some of the corresponding curves are presented for better appreciation in Figures 1 – 3 for boys and girls separately. The tables show the median (M), the Box-Cox power to remove skewness (L) and the coefficient of variation (S) based on sex and age separately for each skinfold. All the reference curves for the four skinfolds were modelled without skewness except triceps skinfold for girls which was found to be positively skewed and as a result requires a negative power (L) to remove the skewness from the data (Table

2). The percentile values are indication of subcutaneous adiposity distribution pattern across age and sex. Comparison of the smoothed median and higher skinfold percentiles across all age between boys and girls revealed that girls consistently have higher values than boys for the four skinfolds. All measured skinfold showed relatively steady increase with age especially in girls.

In boys, median biceps increased from 3.33 mm (3 years) and peak at age 19 years. An initial slow decrease in median biceps was noticed from 3 years to 10 years, then rebounds at 10.5 years and increased steadily to age 19 years. Compared to the median, higher percentiles have earlier rebound after initial decrease in skinfold thickness. For girls, median biceps increased from 4.35 mm at 3 years to 6.61 mm at 19 years while the 97th percentile increased from 7.25 mm at 3 years to 15.53 mm at 19 years. After an initial decrease of median percentile from 3 years (3.80 mm) to 8 years (3.77 mm), it begins to rebound from 8.5 years and peak at 19 years (6.61 mm). Both the 90thh and 97thh percentiles showed similar pattern of decrease in from age 3 years but began to increase 1 year earlier (7.5 years) than median percentile.

For triceps skinfold thickness in boys, median percentile decreased from 5.81 mm (3 years) to 5.00 mm (9 years) then begins to increase at age 9.5 years steadily to 19 years. Similarly, the 97th percentile decreased from 9.47 mm (3 years) to 8.59 mm (8.5 years), then rebounds from 9 years and continues to increase steadily up to adolescence. In girls, median and 97th percentiles of triceps skinfold thickness decreased *ab initio* then rebounds and continues to increase steadily to adolescence.

Median subscapular skinfold for boys showed minimal changes with age. It however plateaus at age 8.50 and 12 years. Ninety-seventh percentile increased from 6.43 mm (3 years) to 8.67 mm and peaks at 19 years. At first, it decreases continuously from 3 years to 6 years then increased appreciably from age 6.5 years to 19 years. Median subscapular skinfold in girls first showed slight decrease from 5.43 mm (3 years) to 5.41 mm (4.5 years), then begins to increase from age 5 years, plateaus at 5 and 8.5 years and peak at 19 years. Ninety-seventh percentile increased appreciably from 3 years and peak at 19 years. It however, plateaus at young age (3 and 7 years).

Median suprailiac skinfold thickness for boys decreased from 4.93 mm (3 years) to 4.76 mm (7.5 years), then begins to increase appreciably from 4.77 mm (8 years) to 6.93 mm (19 years). It plateaus at age 11 and 13.5 years. ninety-seventh percentile increased steadily from 3 years and peak at 19 years. Both median and 97th percentiles for girls showed appreciable increase from 3 years (4.89 vs 7.48 mm) and peak at 19 years (11.84 vs 34.41 mm) respectively.

The skinfold thicknesses for individuals considered underweight were in general, consistently lower across ages, especially in girls. Figures 1 (A and B) gives the comparison of biceps skinfold for underweight and normal weight individuals for boys and girls respectively. Comparison of 97th percentiles between the underweight and normal weight showed that the centiles for the underweight were far below that of their normal weight counterparts for both sexes. The median biceps skinfold for underweight boys was below the 25th percentile for the normal weight while median underweight for girls tracks slightly above the 25th percentile for normal girls.

Figures 2 (C and D) compares triceps skinfold for underweight and normal weight boys and girls. Median triceps skinfold thickness for underweight boys and girls are consistently below the 25th percentile of normal weight individuals. The 97th percentile for boys approximates the 75th percentile at several ages. At age ≈ 14 years, the 97th percentile tracks upwards. The cause of such deviation is not explained but less likely due to artefact during smoothing process. In girls, the 97th percentile also approximates the 75th percentile at early age. At age ≈ 11 years, the 97th percentile for the underweight tracks steadily below the 75th percentile for the normal weight. Again, although the reason for such discrepancy is not explained, that it occurred in girls suggests the tracking may more likely be empiric than artefact during modelling.

The median subscapular skinfold thickness for underweight boys approximates median skinfold for normal weight (Figure 3E). The 97th percentile for underweight individuals however tracks below 75th percentile of the normal weight across all ages. In girls, median subscapular skinfold for the underweight approximates the 10th percentile for the normal weight (Figure 3F). Ninety-seventh percentile for the underweight approximates the 75th percentile from lower age to ≈ 9 years, it then consistently continues to diverge below the 75th percentile of the normal weight across the remaining ages.

The median suprailiac skinfold of underweight boys (Figure 4G) was initially slightly above the 10th percentile of the normal weight individuals at age 5 to ≈11 years then approximates the 10thh percentile up to ≈ 16 years then continues tracking below the 10th percentile. The 97th percentile for the underweight diverges below 90thh percentile of those with normal weight then continues slightly above the 75th percentile. At ≈ 16 years, it crosses the 75th percentile and continues below it. In general, suprailiac skinfold percentiles underweight and normal individuals didn't track properly. In girls, median suprailiac skinfold thickness of individuals identified as underweight was consistently below the 10th percentile of girls with normal weight (Figure 4H). The 97th percentile of the underweight initially approximates the 75th percentile of normal weight girls up to ≈ 9 years, then begins to track appreciably below the 75th percentile of normal weight girls.

Table 1: Bicep skinfold-for-age variables and percentiles by age and sex

	Biceps skinfold (mm)																	
	Boys									Girls								
Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
	edf = 3	edf = 4				edf = 5				edf = 3	edf = 4				edf = 5			
3.00 – 3.49	-0.1224	0.2943	2.26	2.72	3.28	3.9847	4.86	5.96	7.34	0.2953	0.2523	2.55	3.09	3.70	4.3980	5.18	6.06	7.04
3.50 – 3.99	-0.1248	0.2931	2.23	2.68	3.23	3.9194	4.78	5.85	7.20	0.2647	0.2567	2.50	3.03	3.64	4.3400	5.13	6.02	7.02
4.00 – 4.49	-0.1273	0.2919	2.19	2.64	3.18	3.8536	4.69	5.74	7.07	0.2221	0.2628	2.44	2.96	3.56	4.2597	5.06	5.97	7.00
4.50 – 4.99	-0.1296	0.2907	2.16	2.59	3.13	3.7867	4.61	5.64	6.93	0.1797	0.2688	2.37	2.89	3.48	4.1805	4.99	5.92	6.98
5.00 – 5.49	-0.1320	0.2895	2.13	2.55	3.07	3.7189	4.52	5.53	6.79	0.1373	0.2747	2.32	2.82	3.41	4.1024	4.92	5.86	6.97
5.50 – 5.99	-0.1343	0.2883	2.10	2.51	3.02	3.6512	4.44	5.42	6.65	0.0955	0.2803	2.26	2.75	3.33	4.0242	4.84	5.81	6.95
6.00 – 6.49	-0.1367	0.2869	2.06	2.47	2.97	3.5851	4.35	5.31	6.52	0.0544	0.2857	2.21	2.69	3.26	3.9470	4.77	5.75	6.93
6.50 – 6.99	-0.1394	0.2851	2.04	2.43	2.92	3.5230	4.27	5.21	6.38	0.0144	0.2909	2.16	2.63	3.19	3.8759	4.70	5.71	6.92
7.00 – 7.49	-0.1432	0.2832	2.01	2.40	2.88	3.4692	4.20	5.12	6.26	-0.0241	0.2962	2.12	2.58	3.14	3.8181	4.65	5.68	6.93
7.50 – 7.99	-0.1493	0.2817	2.00	2.38	2.85	3.4280	4.15	5.05	6.17	-0.0607	0.3019	2.09	2.54	3.10	3.7819	4.63	5.68	7.00
8.00 – 8.49	-0.1581	0.2810	1.98	2.36	2.83	3.3991	4.11	5.00	6.12	-0.0948	0.3083	2.07	2.52	3.08	3.7732	4.64	5.74	7.12
8.50 – 8.99	-0.1700	0.2815	1.97	2.35	2.81	3.3794	4.09	4.98	6.11	-0.1259	0.3154	2.07	2.52	3.08	3.7923	4.69	5.84	7.32
9.00 – 9.49	-0.1846	0.2832	1.96	2.34	2.80	3.3663	4.08	4.98	6.12	-0.1529	0.3234	2.07	2.53	3.10	3.8352	4.78	5.99	7.58
9.50 – 9.99	-0.2018	0.2861	1.95	2.32	2.78	3.3575	4.08	4.99	6.17	-0.1749	0.3321	2.08	2.54	3.14	3.8973	4.88	6.18	7.90
10.00 – 10.49	-0.2210	0.2901	1.94	2.31	2.77	3.3528	4.09	5.02	6.24	-0.1908	0.3414	2.09	2.57	3.18	3.9750	5.02	6.40	8.26
10.50 – 10.99	-0.2417	0.2953	1.93	2.30	2.77	3.3530	4.10	5.07	6.34	-0.2005	0.3511	2.11	2.60	3.24	4.0672	5.17	6.65	8.67
11.00 – 11.49	-0.2638	0.3015	1.92	2.29	2.76	3.3578	4.13	5.14	6.48	-0.2042	0.3609	2.13	2.64	3.30	4.1753	5.34	6.93	9.12
11.50 – 11.99	-0.2871	0.3085	1.91	2.28	2.76	3.3672	4.16	5.22	6.64	-0.2024	0.3705	2.16	2.69	3.38	4.3019	5.54	7.24	9.60
12.00 – 12.49	-0.3115	0.3158	1.90	2.28	2.76	3.3810	4.20	5.31	6.83	-0.1953	0.3791	2.19	2.75	3.47	4.4460	5.76	7.57	10.10
12.50 – 12.99	-0.3364	0.3228	1.89	2.27	2.76	3.3984	4.25	5.41	7.04	-0.1832	0.3863	2.24	2.81	3.58	4.6049	6.00	7.91	10.59
13.00 – 13.49	-0.3613	0.3292	1.89	2.27	2.77	3.4183	4.30	5.51	7.25	-0.1665	0.3917	2.29	2.89	3.70	4.7728	6.23	8.24	11.05
13.50 – 13.99	-0.3861	0.3349	1.90	2.28	2.78	3.4390	4.34	5.61	7.46	-0.1453	0.3952	2.34	2.98	3.82	4.9434	6.47	8.55	11.45
14.00 – 14.49	-0.4110	0.3397	1.90	2.28	2.79	3.4604	4.39	5.71	7.68	-0.1202	0.3971	2.39	3.06	3.94	5.1137	6.69	8.84	11.78
14.50 – 14.99	-0.4363	0.3437	1.91	2.29	2.80	3.4824	4.43	5.81	7.88	-0.0923	0.3978	2.45	3.15	4.07	5.2847	6.91	9.10	12.08
15.00 – 15.49	-0.4622	0.3468	1.92	2.31	2.81	3.5051	4.48	5.90	8.09	-0.0622	0.3976	2.51	3.24	4.20	5.4570	7.13	9.36	12.34
15.50 – 15.99	-0.4889	0.3492	1.93	2.32	2.83	3.5274	4.52	5.98	8.29	-0.0308	0.3968	2.57	3.33	4.33	5.6303	7.34	9.60	12.57
16.00 – 16.49	-0.5163	0.3511	1.95	2.33	2.84	3.5484	4.55	6.06	8.49	0.0014	0.3955	2.63	3.42	4.46	5.8027	7.55	9.83	12.79
16.50 – 16.99	-0.5444	0.3527	1.96	2.35	2.86	3.5685	4.59	6.14	8.69	0.0339	0.3937	2.69	3.51	4.59	5.9695	7.75	10.04	12.99
17.00 – 17.49	-0.5730	0.3539	1.98	2.36	2.88	3.5874	4.62	6.22	8.89	0.0668	0.3914	2.74	3.60	4.71	6.1289	7.94	10.24	13.15
17.50 – 17.99	-0.6015	0.3547	2.00	2.38	2.89	3.6047	4.65	6.29	9.09	0.1000	0.3887	2.80	3.69	4.83	6.2820	8.11	10.41	13.28
18.00 – 18.49	-0.6300	0.3552	2.01	2.39	2.90	3.6210	4.68	6.36	9.29	0.1334	0.3857	2.85	3.78	4.95	6.4319	8.28	10.58	13.40
18.50 – 18.99	-0.6584	0.3555	2.03	2.41	2.92	3.6373	4.71	6.42	9.49	0.1668	0.3826	2.90	3.86	5.07	6.5811	8.45	10.74	13.52
19.00 – 19.49	-0.6823	0.3558	2.04	2.42	2.93	3.6510	4.73	6.48	9.67	0.1931	0.3801	2.94	3.93	5.17	6.6985	8.58	10.86	13.62

Table 2: Triceps skinfold-for-age variables and percentiles by age and sex

	Triceps skinfold (mm)																	
	Boys									Girls								
Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
	edf = 3	edf = 4				edf = 5				edf = 3	edf = 4				edf = 5			
3.00 – 3.49	0.1224	0.2507	3.46	4.13	4.90	5.8033	6.85	8.05	9.44	0.4421	0.2486	3.90	4.78	5.76	6.8420	8.03	9.32	10.72
3.50 – 3.99	0.1153	0.2499	3.42	4.07	4.83	5.7152	6.74	7.93	9.29	0.4047	0.2491	3.86	4.72	5.67	6.7364	7.91	9.20	10.61
4.00 – 4.49	0.1081	0.2491	3.37	4.01	4.76	5.6270	6.63	7.80	9.14	0.3528	0.2498	3.80	4.62	5.55	6.5906	7.75	9.03	10.44
4.50 – 4.99	0.1010	0.2482	3.33	3.96	4.69	5.5392	6.53	7.67	8.99	0.3009	0.2504	3.75	4.54	5.43	6.4474	7.59	8.86	10.28
5.00 – 5.49	0.0938	0.2473	3.29	3.90	4.62	5.4532	6.42	7.55	8.84	0.2492	0.2510	3.69	4.45	5.32	6.3098	7.43	8.70	10.13
5.50 – 5.99	0.0865	0.2466	3.24	3.85	4.55	5.3707	6.32	7.43	8.70	0.1981	0.2517	3.64	4.37	5.21	6.1787	7.29	8.55	9.98
6.00 – 6.49	0.0789	0.2460	3.20	3.80	4.49	5.2936	6.23	7.32	8.58	0.1482	0.2528	3.58	4.28	5.11	6.0554	7.15	8.41	9.86
6.50 – 6.99	0.0708	0.2457	3.17	3.75	4.43	5.2230	6.15	7.22	8.47	0.1002	0.2547	3.52	4.21	5.01	5.9462	7.04	8.30	9.77
7.00 – 7.49	0.0616	0.2460	3.13	3.70	4.38	5.1605	6.08	7.14	8.38	0.0548	0.2576	3.48	4.14	4.93	5.8620	6.95	8.24	9.74
7.50 – 7.99	0.0504	0.2469	3.10	3.67	4.33	5.1092	6.02	7.08	8.32	0.0128	0.2620	3.44	4.10	4.88	5.8160	6.92	8.24	9.81
8.00 – 8.49	0.0365	0.2486	3.07	3.63	4.29	5.0711	5.98	7.05	8.30	-0.0249	0.2682	3.42	4.08	4.87	5.8184	6.96	8.33	9.98
8.50 – 8.99	0.0191	0.2512	3.05	3.61	4.27	5.0468	5.97	7.05	8.32	-0.0575	0.2760	3.41	4.08	4.89	5.8695	7.06	8.51	10.29
9.00 – 9.49	-0.0024	0.2545	3.03	3.59	4.25	5.0368	5.97	7.07	8.38	-0.0843	0.2853	3.42	4.10	4.94	5.9643	7.23	8.78	10.71
9.50 – 9.99	-0.0279	0.2586	3.02	3.58	4.24	5.0398	5.99	7.13	8.49	-0.1046	0.2960	3.43	4.14	5.02	6.0993	7.45	9.13	11.24
10.00 – 10.49	-0.0568	0.2635	3.01	3.57	4.24	5.0542	6.03	7.21	8.63	-0.1176	0.3078	3.46	4.20	5.12	6.2673	7.71	9.55	11.88
10.50 – 10.99	-0.0886	0.2692	3.00	3.57	4.25	5.0785	6.09	7.31	8.82	-0.1235	0.3205	3.49	4.26	5.23	6.4634	8.03	10.03	12.60
11.00 – 11.49	-0.1228	0.2755	3.00	3.57	4.26	5.1110	6.15	7.44	9.04	-0.1229	0.3340	3.52	4.33	5.37	6.6852	8.38	10.57	13.42
11.50 – 11.99	-0.1588	0.2820	3.00	3.58	4.28	5.1516	6.24	7.59	9.30	-0.1168	0.3478	3.55	4.41	5.52	6.9328	8.77	11.17	14.32
12.00 – 12.49	-0.1954	0.2884	3.01	3.59	4.30	5.1987	6.32	7.75	9.59	-0.1058	0.3615	3.59	4.50	5.68	7.2059	9.20	11.82	15.29
12.50 – 12.99	-0.2306	0.2943	3.02	3.60	4.33	5.2473	6.41	7.92	9.88	-0.0907	0.3748	3.63	4.60	5.86	7.4997	9.66	12.51	16.30
13.00 – 13.49	-0.2622	0.2999	3.03	3.62	4.35	5.2908	6.50	8.07	10.16	-0.0719	0.3870	3.68	4.70	6.05	7.8077	10.13	13.21	17.32
13.50 – 13.99	-0.2893	0.3049	3.04	3.63	4.37	5.3251	6.57	8.21	10.42	-0.0496	0.3980	3.72	4.81	6.24	8.1256	10.61	13.91	18.30
14.00 – 14.49	-0.3122	0.3092	3.04	3.63	4.38	5.3505	6.62	8.32	10.64	-0.0239	0.4077	3.77	4.93	6.45	8.4522	11.10	14.61	19.26
14.50 – 14.99	-0.3312	0.3129	3.04	3.63	4.39	5.3683	6.66	8.41	10.83	0.0049	0.4165	3.81	5.04	6.66	8.7876	11.60	15.30	20.18
15.00 – 15.49	-0.3473	0.3158	3.04	3.63	4.39	5.3813	6.70	8.48	10.98	0.0364	0.4246	3.85	5.15	6.87	9.1296	12.10	15.99	21.07
15.50 – 15.99	-0.3617	0.3180	3.04	3.63	4.39	5.3895	6.72	8.54	11.10	0.0702	0.4322	3.88	5.26	7.08	9.4727	12.60	16.66	21.92
16.00 – 16.49	-0.3755	0.3195	3.04	3.63	4.39	5.3929	6.73	8.58	11.20	0.1060	0.4393	3.90	5.36	7.29	9.8113	13.09	17.32	22.73
16.50 – 16.99	-0.3888	0.3207	3.04	3.63	4.39	5.3903	6.74	8.60	11.27	0.1430	0.4460	3.91	5.45	7.48	10.1418	13.57	17.95	23.48
17.00 – 17.49	-0.4011	0.3217	3.03	3.62	4.38	5.3792	6.73	8.61	11.32	0.1809	0.4524	3.90	5.52	7.67	10.4643	14.04	18.55	24.19
17.50 – 17.99	-0.4126	0.3225	3.02	3.61	4.36	5.3590	6.71	8.60	11.35	0.2192	0.4586	3.87	5.59	7.86	10.7829	14.50	19.14	24.87
18.00 – 18.49	-0.4234	0.3234	3.01	3.59	4.34	5.3324	6.69	8.58	11.35	0.2576	0.4646	3.84	5.65	8.04	11.1004	14.95	19.72	25.53
18.50 – 18.99	-0.4339	0.3242	2.99	3.57	4.31	5.3036	6.66	8.56	11.36	0.2960	0.4704	3.79	5.71	8.22	11.4182	15.41	20.30	26.19
19.00 – 19.49	-0.4427	0.3250	2.98	3.55	4.29	5.2793	6.63	8.54	11.36	0.3262	0.4750	3.74	5.74	8.35	11.6690	15.77	20.75	26.70

Table 3: Subscapular skinfold-for-age variables and percentiles by age and sex

	Subscapular skinfold (mm)																	
	Boys									Girls								
Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
	edf = 2	edf = 3				edf = 5				edf = 3	edf = 4				edf = 5			
3.00 – 3.49	0.0155	0.2622	2.79	3.33	3.97	4.7304	5.63	6.70	7.97	-0.0187	0.2705	3.18	3.80	4.55	5.4440	6.52	7.82	9.38
3.50 – 3.99	0.0092	0.2607	2.81	3.35	3.99	4.7429	5.64	6.71	7.98	-0.0280	0.2707	3.18	3.80	4.54	5.4358	6.51	7.81	9.38
4.00 – 4.49	0.0029	0.2592	2.83	3.37	4.00	4.7553	5.65	6.72	7.98	-0.0409	0.2710	3.17	3.79	4.53	5.4249	6.50	7.81	9.38
4.50 – 4.99	-0.0033	0.2576	2.85	3.38	4.01	4.7666	5.66	6.72	7.98	-0.0539	0.2713	3.17	3.79	4.52	5.4167	6.50	7.81	9.39
5.00 – 5.49	-0.0094	0.2561	2.86	3.40	4.03	4.7756	5.67	6.72	7.98	-0.0671	0.2718	3.17	3.78	4.52	5.4148	6.50	7.82	9.42
5.50 – 5.99	-0.0152	0.2546	2.88	3.41	4.04	4.7814	5.67	6.72	7.97	-0.0804	0.2729	3.18	3.79	4.52	5.4200	6.51	7.84	9.47
6.00 – 6.49	-0.0209	0.2532	2.89	3.42	4.04	4.7834	5.66	6.71	7.96	-0.0939	0.2748	3.18	3.79	4.53	5.4328	6.54	7.89	9.55
6.50 – 6.99	-0.0267	0.2518	2.90	3.42	4.04	4.7818	5.66	6.70	7.94	-0.1074	0.2777	3.18	3.79	4.54	5.4551	6.58	7.96	9.67
7.00 – 7.49	-0.0337	0.2507	2.91	3.43	4.05	4.7802	5.65	6.69	7.93	-0.1203	0.2817	3.19	3.81	4.56	5.4950	6.64	8.07	9.85
7.50 – 7.99	-0.0428	0.2501	2.92	3.44	4.05	4.7853	5.66	6.70	7.93	-0.1323	0.2865	3.20	3.83	4.61	5.5621	6.75	8.23	10.09
8.00 – 8.49	-0.0547	0.2502	2.93	3.45	4.07	4.7994	5.67	6.72	7.97	-0.1431	0.2921	3.23	3.88	4.67	5.6622	6.90	8.45	10.42
8.50 – 8.99	-0.0696	0.2514	2.94	3.46	4.08	4.8222	5.71	6.77	8.05	-0.1524	0.2987	3.27	3.93	4.76	5.7918	7.09	8.73	10.84
9.00 – 9.49	-0.0874	0.2540	2.95	3.48	4.10	4.8529	5.76	6.84	8.16	-0.1597	0.3062	3.31	4.00	4.86	5.9450	7.32	9.07	11.33
9.50 – 9.99	-0.1077	0.2578	2.96	3.49	4.13	4.8910	5.82	6.94	8.31	-0.1647	0.3145	3.37	4.08	4.98	6.1236	7.58	9.46	11.89
10.00 – 10.49	-0.1291	0.2628	2.97	3.50	4.15	4.9366	5.89	7.07	8.51	-0.1673	0.3231	3.43	4.17	5.12	6.3267	7.88	9.89	12.54
10.50 – 10.99	-0.1501	0.2686	2.98	3.52	4.18	4.9885	5.98	7.21	8.73	-0.1675	0.3318	3.49	4.27	5.27	6.5504	8.21	10.37	13.24
11.00 – 11.49	-0.1691	0.2751	2.98	3.53	4.21	5.0450	6.08	7.37	8.99	-0.1656	0.3405	3.56	4.38	5.44	6.7927	8.56	10.89	13.99
11.50 – 11.99	-0.1846	0.2816	2.99	3.55	4.25	5.1086	6.18	7.54	9.26	-0.1615	0.3487	3.64	4.50	5.61	7.0521	8.94	11.44	14.78
12.00 – 12.49	-0.1947	0.2876	3.00	3.58	4.29	5.1815	6.30	7.72	9.54	-0.1551	0.3561	3.73	4.63	5.80	7.3261	9.33	12.00	15.58
12.50 – 12.99	-0.1972	0.2930	3.02	3.61	4.34	5.2630	6.42	7.90	9.81	-0.1461	0.3624	3.82	4.77	6.00	7.6091	9.73	12.56	16.37
13.00 – 13.49	-0.1910	0.2978	3.04	3.65	4.40	5.3506	6.55	8.09	10.07	-0.1342	0.3675	3.92	4.91	6.20	7.8962	10.13	13.11	17.12
13.50 – 13.99	-0.1771	0.3017	3.07	3.69	4.47	5.4456	6.68	8.27	10.31	-0.1190	0.3716	4.02	5.06	6.41	8.1864	10.53	13.64	17.82
14.00 – 14.49	-0.1582	0.3046	3.10	3.75	4.55	5.5529	6.83	8.45	10.54	-0.1004	0.3747	4.12	5.21	6.63	8.4819	10.92	14.16	18.49
14.50 – 14.99	-0.1371	0.3062	3.15	3.82	4.64	5.6767	6.98	8.64	10.76	-0.0793	0.3773	4.22	5.36	6.85	8.7854	11.33	14.68	19.13
15.00 – 15.49	-0.1155	0.3067	3.22	3.90	4.75	5.8196	7.16	8.85	11.00	-0.0569	0.3796	4.33	5.53	7.08	9.1004	11.74	15.21	19.78
15.50 – 15.99	-0.0940	0.3062	3.30	4.01	4.89	5.9818	7.35	9.07	11.24	-0.0340	0.3819	4.43	5.69	7.32	9.4272	12.17	15.76	20.44
16.00 – 16.49	-0.0725	0.3050	3.39	4.13	5.04	6.1622	7.56	9.31	11.50	-0.0108	0.3845	4.54	5.86	7.56	9.7629	12.62	16.32	21.13
16.50 – 16.99	-0.0508	0.3032	3.50	4.26	5.20	6.3575	7.79	9.57	11.77	0.0125	0.3871	4.64	6.02	7.80	10.1036	13.07	16.90	21.83
17.00 – 17.49	-0.0277	0.3009	3.61	4.40	5.37	6.5606	8.02	9.82	12.04	0.0360	0.3896	4.74	6.18	8.05	10.4454	13.53	17.48	22.53
17.50 – 17.99	-0.0031	0.2983	3.73	4.55	5.55	6.7654	8.25	10.07	12.29	0.0594	0.3920	4.83	6.34	8.29	10.7870	13.98	18.05	23.21
18.00 – 18.49	0.0226	0.2955	3.84	4.69	5.72	6.9694	8.48	10.32	12.54	0.0828	0.3944	4.92	6.50	8.53	11.1285	14.43	18.62	23.89
18.50 – 18.99	0.0486	0.2926	3.96	4.84	5.90	7.1728	8.71	10.56	12.77	0.1064	0.3967	5.01	6.66	8.77	11.4707	14.89	19.19	24.57
19.00 – 19.49	0.0703	0.2901	4.06	4.96	6.04	7.3428	8.90	10.76	12.97	0.1250	0.3984	5.07	6.78	8.96	11.7406	15.25	19.64	25.10

Table 4: Suprailiac skinfold-for-age variables and percentiles by age and sex

	Suprailiac skinfold (mm)																	
	Boys									Girls								
Age (years)	L	S	3rd	10th	25th	50th (M)	75th	90th	97th	L	S	3rd	10th	25th	50th (M)	75th	90th	97th
	edf = 2	edf = 3				edf = 4				edf = 2	edf = 3				edf = 4			
3.00 – 3.49	0.1244	0.2071	3.24	3.74	4.31	4.9568	5.68	6.50	7.42	-1.0525	0.1908	3.85	4.24	4.71	5.3118	6.09	7.14	8.65
3.50 – 3.99	0.1058	0.2099	3.21	3.71	4.28	4.9323	5.67	6.50	7.44	-1.0212	0.1969	3.80	4.19	4.68	5.2923	6.09	7.18	8.76
4.00 – 4.49	0.0870	0.2128	3.18	3.68	4.26	4.9079	5.65	6.50	7.45	-0.9778	0.2053	3.73	4.13	4.63	5.2660	6.10	7.24	8.90
4.50 – 4.99	0.0683	0.2156	3.15	3.65	4.23	4.8840	5.63	6.49	7.47	-0.9345	0.2137	3.66	4.07	4.59	5.2427	6.11	7.30	9.05
5.00 – 5.49	0.0496	0.2183	3.13	3.63	4.20	4.8608	5.62	6.49	7.49	-0.8911	0.2222	3.59	4.02	4.55	5.2262	6.13	7.37	9.20
5.50 – 5.99	0.0309	0.2210	3.10	3.60	4.17	4.8385	5.60	6.49	7.51	-0.8477	0.2308	3.54	3.97	4.52	5.2205	6.16	7.46	9.38
6.00 – 6.49	0.0122	0.2236	3.08	3.57	4.15	4.8178	5.59	6.49	7.53	-0.8043	0.2395	3.49	3.94	4.50	5.2310	6.21	7.57	9.58
6.50 – 6.99	-0.0065	0.2260	3.06	3.55	4.13	4.8001	5.58	6.49	7.55	-0.7609	0.2483	3.45	3.92	4.50	5.2628	6.28	7.71	9.82
7.00 – 7.49	-0.0252	0.2284	3.04	3.54	4.11	4.7879	5.58	6.50	7.58	-0.7175	0.2573	3.43	3.91	4.52	5.3191	6.39	7.89	10.11
7.50 – 7.99	-0.0439	0.2306	3.03	3.52	4.10	4.7842	5.58	6.52	7.62	-0.6741	0.2665	3.43	3.93	4.57	5.4013	6.53	8.11	10.45
8.00 – 8.49	-0.0626	0.2329	3.03	3.52	4.10	4.7908	5.60	6.56	7.69	-0.6308	0.2760	3.43	3.96	4.63	5.5103	6.70	8.38	10.86
8.50 – 8.99	-0.0813	0.2353	3.03	3.53	4.11	4.8081	5.63	6.61	7.77	-0.5874	0.2858	3.45	4.00	4.71	5.6456	6.91	8.69	11.33
9.00 – 9.49	-0.1000	0.2377	3.04	3.54	4.13	4.8364	5.67	6.67	7.87	-0.5440	0.2960	3.47	4.06	4.81	5.8055	7.15	9.05	11.86
9.50 – 9.99	-0.1187	0.2403	3.06	3.56	4.16	4.8758	5.73	6.76	8.00	-0.5006	0.3065	3.51	4.13	4.93	5.9912	7.43	9.46	12.46
10.00 – 10.49	-0.1374	0.2431	3.08	3.59	4.20	4.9248	5.80	6.86	8.15	-0.4572	0.3170	3.56	4.22	5.07	6.2038	7.75	9.92	13.12
10.50 – 10.99	-0.1561	0.2461	3.10	3.62	4.24	4.9815	5.88	6.98	8.31	-0.4138	0.3275	3.61	4.31	5.23	6.4443	8.10	10.43	13.84
11.00 – 11.49	-0.1748	0.2495	3.13	3.65	4.28	5.0438	5.97	7.11	8.50	-0.3704	0.3378	3.67	4.43	5.41	6.7129	8.49	10.99	14.61
11.50 – 11.99	-0.1935	0.2531	3.15	3.69	4.33	5.1106	6.07	7.24	8.71	-0.3271	0.3479	3.74	4.55	5.60	7.0080	8.92	11.59	15.43
12.00 – 12.49	-0.2122	0.2568	3.18	3.72	4.38	5.1817	6.17	7.39	8.93	-0.2837	0.3576	3.82	4.68	5.82	7.3265	9.38	12.23	16.29
12.50 – 12.99	-0.2310	0.2606	3.21	3.76	4.43	5.2572	6.28	7.55	9.16	-0.2403	0.3667	3.90	4.83	6.04	7.6646	9.86	12.89	17.18
13.00 – 13.49	-0.2497	0.2644	3.25	3.81	4.49	5.3373	6.39	7.72	9.41	-0.1969	0.3753	3.98	4.98	6.28	8.0186	10.36	13.58	18.07
13.50 – 13.99	-0.2684	0.2681	3.29	3.86	4.55	5.4235	6.51	7.90	9.68	-0.1535	0.3833	4.06	5.13	6.53	8.3853	10.88	14.28	18.96
14.00 – 14.49	-0.2871	0.2716	3.33	3.91	4.63	5.5182	6.65	8.09	9.96	-0.1101	0.3907	4.14	5.28	6.78	8.7616	11.41	14.98	19.84
14.50 – 14.99	-0.3058	0.2748	3.38	3.97	4.71	5.6233	6.79	8.29	10.26	-0.0668	0.3976	4.21	5.43	7.03	9.1456	11.95	15.69	20.71
15.00 – 15.49	-0.3245	0.2777	3.44	4.05	4.80	5.7400	6.95	8.52	10.59	-0.0234	0.4041	4.28	5.58	7.29	9.5358	12.49	16.40	21.56
15.50 – 15.99	-0.3432	0.2803	3.51	4.13	4.90	5.8681	7.12	8.75	10.94	0.0200	0.4101	4.34	5.73	7.55	9.9305	13.04	17.11	22.40
16.00 – 16.49	-0.3619	0.2825	3.59	4.22	5.01	6.0064	7.30	9.01	11.30	0.0634	0.4159	4.39	5.87	7.81	10.3280	13.60	17.81	23.23
16.50 – 16.99	-0.3806	0.2845	3.68	4.32	5.12	6.1525	7.49	9.27	11.68	0.1068	0.4215	4.43	6.01	8.06	10.7268	14.15	18.51	24.05
17.00 – 17.49	-0.3993	0.2863	3.76	4.42	5.24	6.3033	7.69	9.54	12.08	0.1502	0.4269	4.46	6.14	8.32	11.1257	14.70	19.21	24.84
17.50 – 17.99	-0.4180	0.2879	3.85	4.52	5.37	6.4558	7.89	9.81	12.47	0.1936	0.4322	4.47	6.26	8.57	11.5243	15.25	19.90	25.63
18.00 – 18.49	-0.4367	0.2894	3.94	4.63	5.49	6.6085	8.08	10.08	12.88	0.2369	0.4374	4.47	6.36	8.81	11.9226	15.81	20.59	26.40
18.50 – 18.99	-0.4554	0.2910	4.03	4.73	5.61	6.7610	8.28	10.36	13.29	0.2803	0.4426	4.45	6.46	9.05	12.3208	16.36	21.27	27.17
19.00 – 19.49	-0.4711	0.2923	4.11	4.82	5.72	6.8885	8.45	10.60	13.65	0.3145	0.4466	4.43	6.53	9.24	12.6346	16.79	21.81	27.76

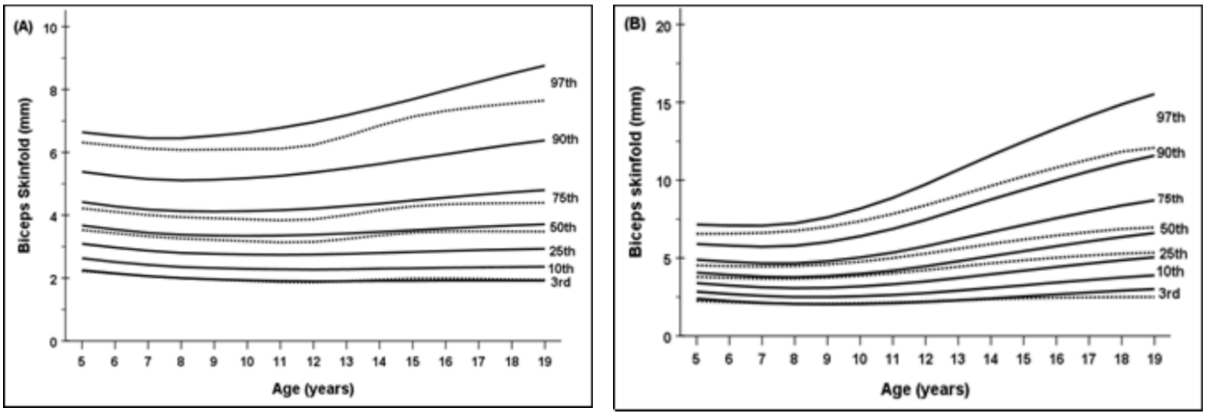

Figure 1: Comparison of smoothed percentile curves of biceps skinfold-for-age curves for boys (A) and girls (B) across age. Solid lines represent percentile curves for Nigerian children and adolescents; dotted lines are corresponding curves for individuals classified as underweight [BMI (kg/m^2) Z-score between < 2 and < 3] using the 2007 WHO growth reference.

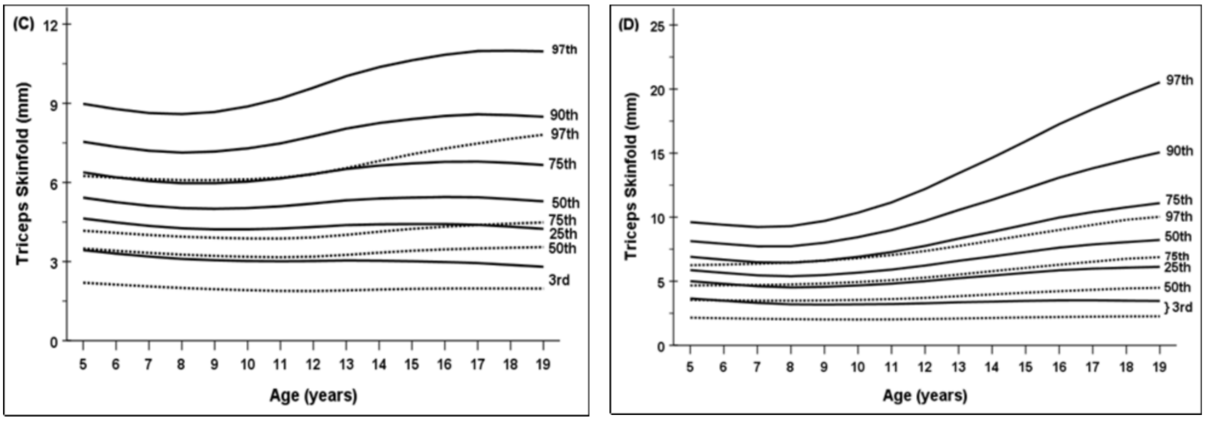

Figure 2: Comparison of smoothed percentile curves of triceps skinfold-for-age curves for boys (C) and girls (D) across age. Solid lines represent percentile curves for Nigerian children and adolescents; dotted lines are corresponding curves for individuals classified as underweight [BMI (kg/m^2) Z-score between < 2 and < 3] using the 2007 WHO growth reference

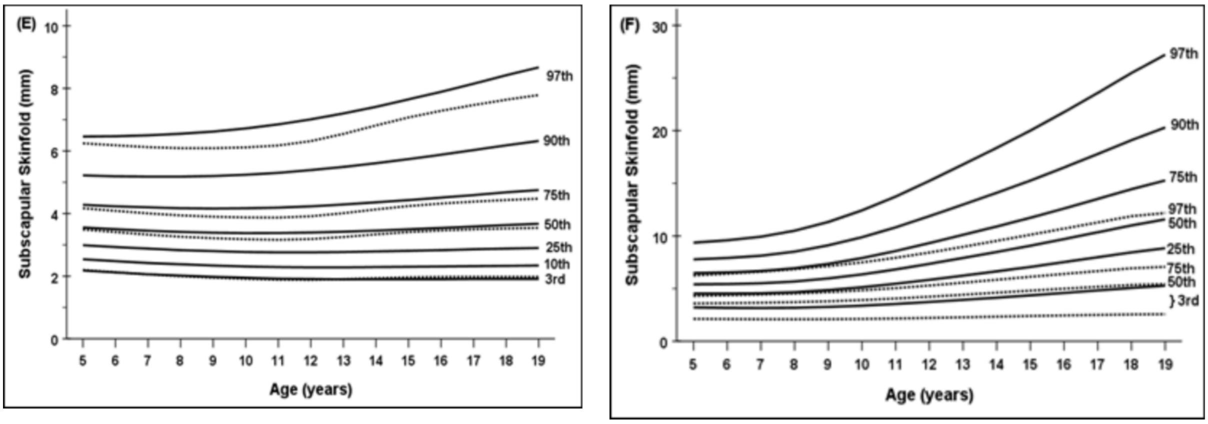

Figure 3: Comparison of smoothed percentile curves of subscapular skinfold-for-age curves for boys (E) and girls (F) across age. Solid lines represent percentile curves for Nigerian children and adolescents; dotted lines are corresponding curves for individuals classified as underweight [BMI (kg/m^2) Z-score between < 2 and < 3] using the 2007 WHO growth reference.

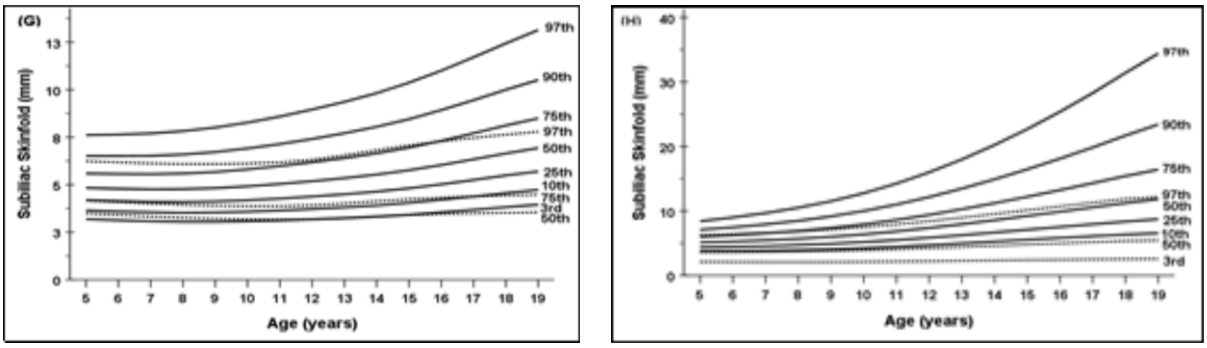

Figure 4: Comparison of smoothed percentile curves of suprailiac skinfold-for-age curves for boys (G) and girls (H) across age. Solid lines represent percentile curves for Nigerian children and adolescents; dotted lines are corresponding curves for individuals classified as underweight [BMI (kg/m^2) *Z*-score between < 2 and < 3] using the 2007 WHO growth reference.

DISCUSSION

This cross-sectional study is the first and largest to present age- and sex-specific smoothed curves for skinfold thickness percentiles based on randomly selected sample of 6,909 children and adolescents aged 3 – 19.49 years in Nasarawa State Nigeria. The study provides a reference data for four skinfold thicknesses and parameters for calculating their Z-scores and as a simple and non-invasive means of estimating subcutaneous adiposity in Nigerian children and adolescents aged 3 – 19 years. Although BMI have been routinely used to assess underweight, the percentile and z-scores of skinfold thicknesses presented in this study makes for improved understanding of both truncal (in this case the subscapular and suprailiac) and peripheral (the biceps and triceps) fat distribution. Skinfold thickness and BMI percentiles have long been recommended by the WHO for use globally as indicators of nutritional status [28]. These percentiles were generated based on US data. The WHO 2007 skinfold percentiles although developed from data from other countries in addition to the US, only considers children 3 – 60 months old. Potential problem and weakness with the WHO published triceps and subscapular skinfold percentiles include its applicability to Nigerian population is unknown, its ability to predict future health risk is not clear and no specific recommendations were made for adolescent skinfolds. Demographics, socioeconomics and cultural practices are some factors responsible for variabilities of anthropometric variables across races.

We observe sexual dimorphism in biceps, triceps, subscapular and suprailiac skinfold thicknesses. Compared with other published references of skinfold thicknesses, we found lower skinfold thicknesses from our sample [3,16,17,29,30].

Both the percentiles and Z-scores generated from the present study will enhance analyses of truncal and peripheral distribution of subcutaneous fat. Skinfold thicknesses while receiving considerable attention in recent years, has not been widely adopted in selecting risk factors than BMI for children aged 4 – 9 years [31] and the wide spread use of BMI expressions for estimating percentage body fat in children than skinfold thickness [10]. While skinfold thickness is an indicator of whole-body adiposity and is sensitive to variations in nutritional status [32], a study found that BMI to correlate with cardiovascular disease complications than centralized deposition of body fat determined by skinfold [33]. Therefore, the choice of including both BMI and skinfold thicknesses depends on what is being assessed.

Bearing in mind that there is no national reference that the current study can be compared to, data for the new reference curves are generated based on careful measurements of skinfold thickness with minimal erroneous measurements. Training of research assistant was performed prior to the commencement of the study and comprised repetitive measurements of the same participants by the research assistants until the measurement procedures were standardized. Therefore, high quality measurement is a sine qua non for high intra-observer reliability and reliability of the study outcomes. It is our hope that other investigators in Nigeria willing to conduct studies on skinfold thickness are encouraged to toe the line of high-quality control during skinfold data collection.

No study has been conducted in Nigeria to assess these four skinfold thicknesses and to establish their centile patterns either at national, subnational or by investigators. The skinfold Z-scores from this study will ease age- and sex-specific comparisons by other investigators. We have provided formula and the various required L, M and S parameters in Tables 1 – 4 for calculating the right age- and sex-specific skinfold Z-scores. The Z-scores will indicate how many standard deviations individual skinfold thickness is from the mean in either positive or negative direction.

The skinfold reference data provided in this study provide the prevailing skinfold thickness of children and adolescents in Nasarawa State, Nigeria and should not be considered as standard of skinfold thickness or growth standard of children in Nigeria since participants were not recruited based on "optimal conditions" such as healthy environmental conditions rather the data should be considered as a reference for future studies both in Nigeria and sub-Saharan Africa. Needless to say, to our knowledge, study is one of the first in Nigeria and sub-Saharan Africa to develop centile curves for four skinfold thicknesses that adopts a methodology in keeping with current recommendations regarding sampling techniques and curve fitting by the WHO [34]. Without considering these curves are based on children and adolescents from Nigeria, we believe that they can also be useful in other regional countries with similar sociodemographic and economic settings.

Our results showed that only few individuals in the present study were overweight and none were identified as obese. Although obesity is a growing global phenomenon [35-37] as well as in many developing countries [35,36], it seems that the double burden of undernutrition and overnutrition problems is still not the case in urban and rural settings of Nasarawa State. Notwithstanding, as seen from Figures 1 – 4, the median and 97th percentiles of subjects classified as underweight by BMI criteria do not track properly and in some instances the chart for the underweight crosses that of normal weigh subjects. Therefore, the patterns of median skinfold presented in this study are inadequate, nevertheless to determine the cut-off point of skinfold percentiles to accurately classify underweight in children and adolescent should not be adopted for this goal. Rather, to determine the maximum skinfold percentile cut-points to classified underweight would require another screening or diagnostic tool known as the receiver operating characteristics or its proxy.

Major strengths of our study are its standardized measurements, accommodation of wide age range, relatively large sample size that results in curves with stable extreme percentile. Unfortunately, some of the limitations of our study include its use of cross-sectional data collection and limited sample size. Longitudinal data are more appropriate for determining subcutaneous fat distribution in growing children than cross-sectional as the former has the advantage of showing changes in fat distribution during child growth and development than the latter. The flexibility that goes with Box-Cox Power transformation smoothing techniques may lead to curves with slightly different fitting based on the choice of parameters entered by the investigator. In addition, data collection began at age 3 years, makes it impossible to capture changes in skinfold thickness among younger children especially for children under five years.

Further Research: Further research is needed to determine the skinfold reference data at national, geopolitical and state levels. Furthermore, further research is needed to explore the use of skinfold thicknesses for nutritional diagnosis of undernutrition (perhaps due to food insecurity or crisis) among children and adolescents and to investigate whether adiposity assessed via skinfold thickness is an aetiology of cardiovascular disease. This is so because effective undernutrition prevention and treatment programmes and efforts require reliable identification of the risk population. Also, future research should investigate plausible means of separating body mass from subcutaneous fat distribution.

CONCLUSION

In conclusion, the present study provides for the first-time age- and sex-specific standardized reference percentile ranges and Z-scores for biceps, triceps, subscapular and suprailiac skinfold thicknesses. Because the reference centiles and parameters for calculating the Z-scores were developed from data collected from representative sample of children and adolescents in Nigeria, they provide an essential assessment tool and reference excerpt both locally and to other sub-Saharan countries with similar cultural, ethnic and sociodemographic settings to Nigeria.

ACKNOWLEDGEMENTS

The cooperation of school authorities, teachers, parents and participants is highly appreciated. We also thank the efforts of the entire research assistants in facilitating the data collection.

Funding

Not applicable.

Authors' contributions

MN was responsible for data collection, management and analyses; all authors were involved from the conceptual construct, design, manuscript write-up, interpretation, critical review of the manuscript, read and gave their approval of the final manuscript. None of the authors reported potential conflict of interest related to this study.

REFERENCES

1. Summary of Child Survival Partnership (2013). The Lancet undernutrition series.
2. National Bureau of Statistics (2018). National Nutrition and Health Survey.
3. Addo OY, Himes J H. (2010). Reference curves for triceps and subscapular skinfold thicknesses in US children and adolescents. *A J Clin Nutr.* 91:635-642.
4. Wells JC, Fewtrell MS. (2006). Measuring body composition. *Archives of Disease in Childhood* 91(7):612–617.
5. Heyward VH, Wagner DR. (2004). Applied Body Composition. 2nd ed. Champaign, IL: *Human Kinetics*. 49-66.
6. L'Abée C, Visser GH, Liem ET, Kok DE, Sauer PJ, Stolk RP. (2010). Comparison of methods to assess body fat in non-obese six to seven-year-old children. *Clin Nutr.* 29(3):317–322.

7. Fichna P, Skowronska B. (2008). Obesity and metabolic syndrome in children and youth. *Family Medicine and Primary Care Review* 2:269–278.
8. Suliga E. (2006). Anthropometrical methods of assessing the nutritional status of children and adolescents. *Paediatr Pol*. 81(10):739–746.
9. Steinberger J, Jacobs DR, Raatz S, Moran A, Hong CP, Sinaiko AR. (2005). Comparison of body fatness measurements by BMI and skinfolds vs dual energy X-ray absorptiometry and their relation to cardiovascular risk factors in adolescents. *Intnl J Obesity (London)* 29:1346 – 52.
10. Goodpaster, B. H. (2002). Measuring body fat distribution and content in humans. *Current Opinion in Clinical Nutrition and Metabolic Care* 5(5):481–487.
11. Wagner DR, Heyward VH. (1999). Techniques of body composition assessment: a review of laboratory and field methods. Res Q Exerc Sport. 70(2):135–149.
12. Andaki AC, Quadros TM, Gordia AP, Mota J, Tinôco AL, Mendes EL. (2017). Skinfold reference curves and their use in predicting metabolic syndrome risk in children. *Journal of Paediatrics (Rio J)* 93:490 – 6.
13. Freedman DS, Serdula MK, Srinivasan SR, Berenson GS. (1999). Relation of circumferences and skinfold thicknesses to lipid and insulin concentrations in children and adolescents: the Bogalusa Heart Study. *American Journal of Clinical Nutrition* 69(2):308–317.
14. WHO Multicentre Growth Reference Study Group (2007). WHO Child Growth Standards: Head circumference-for-age, arm circumference-for-age, triceps skinfold-for-age and subscapular skinfold-for-age: Methods and development. Geneva: *World Health Organization*.
15. de Onis M, Onyango A, Borghi E, Siyam A, Blössner M, Lutter C. (2012). Worldwide implementation of the WHO Child Growth Standards. *Public Health Nutrition* 15: 1603–10.
16. Kuhle S, Ashley-Martin J, Maguire B, Hamilton CD. (2016). Percentile curves for skinfold thickness for Canadian children and youth. *PeerJ* 4: e2247; DOI10.7717/peerj.2247
17. Jaworski M, Kułaga Z, Płudowski P, Grajda A, Gurzkowska B, Napieralska E, Świąder A, Pan H, Litwin M, *et al.,* (2012). Population-based centile curves for triceps, subscapular, and abdominal skinfold thicknesses in Polish children and adolescents – the OLAF study. *European Journal of Paediatrics* 171:1215 – 1221.
18. Amoo-Tella SY, Danborno BS, Akuyam S, Adebisi SS. (2017). Gender-and-age-related differences in anthropometric and body composition parameters in Nigerians, Zaria, Nigeria. *Journal Experimental and Clinical Anatomy* 16:137 – 46.
19. Senbanjo IO, Oshikoya KA, Njokanma OF. (2014). Upper arm composition and nutritional status of schoolchildren and adolescents in Abeokuta, Southwest Nigeria. *World Journal of Paediatrics* 10:336 – 342.
20. Izuora AN, Animasahun BA, Nwodo U, Ibeabuchi NM, Njokanma OF, Renner J. (2013). K. Assessment of overweight and obesity among Nigerian children and adolescents using triceps skinfold and body mass index. *Clinical Obesity* 3(3-4):103 – 111.
21. Stewart A, Marfell-Jones M, Olds T, de Ridder H. (2011). International standards for anthropometric assessment. Lower Hutt: *International Society for Advancement of Kineanthropometry*.
22. Fisher RA. (1921). On the “probable error” of a coefficient of correlation deduced from a small sample. *Metron*. 1:1 – 32.
23. Fleiss JL. (1986). The design and analysis of clinical experiments. New York: *John Wiley*. 236.
24. Cole TJ. (1990). The LMS method for constructing normalized growth standards. *European Journal of Clinical Nutrition* 44:45–60.
25. Cole TJ, Green PJ. (1992). Smoothing reference centile curves: the LMS method and penalized likelihood. *Statistics in Medicine* 11:1305–19.
26. Pan H, Cole TJ. (2004). A comparison of goodness of fit tests for age related reference ranges. *Statistics in Medicine* 23:1749–1765.
27. Royston P, Wright EM. (2000). Goodness of fit statistics for age specific reference intervals. *Statistics in Medicine* 19:2943–2962.
28. Must A, Dallal GE. (1991). Dietz WH. Reference data for obesity: 85th and 95th percentiles of body mass index (wt/ht2) and triceps skinfold thickness. *American Journal of Clinical Nutrition* 53:839–46.
29. McDowell MA, Fryar CD, Ogden CL, Flegal KM. (2008). Anthropometric reference data for children and adults: United States, 2003–2006. *National Health Statistics Reports* Number 10; October 22. http://www.cdc.gov/nchs/data/nhsr/nhsr010.pdf. 2008 (Accessed 3 September, 2020).
30. Cronk CE, Roche AF. (1982). Race- and sex-specific reference data for triceps and subscapular skinfolds and weight/stature. *American Journal of Clinical Nutrition* 35(2):347–354.
31. Geiss HC, Parhofer KG, Schwandt P. (2001). Parameters of childhood obesity and their relationship to cardiovascular risk factors in healthy prepubescent children. *International Journal of Obesity and Related Metabolic Disorders* 25:830–7.
32. Morrison JA, Barton BA, Biro FM, Daniels SR, Sprecher DL. (1999). Overweight, fat patterning, and cardiovascular disease risk factors in black and white boys. *Journal of Paediatrics* 135:451–7.
33. Lasserre AM, Chiolero A, Paccaud F, Bovet P. (2007). Worldwide trends in childhood obesity. *Swiss Medicine Weekly* 137(9-10):157–158.
34. Kosti RI, Panagiotakos DB. (2006). The epidemic of obesity in children and adolescents in the world. *Central European Journal of Public Health* 14:151–159.
35. Lobstein T, Baur L, Uauy R. (2004). Obesity in children and young people: a crisis in public health. *Obesity Review* 5 Suppl. 1:4–104.
36. Popkin BM, Gordon-Larsen P. (2004). The nutrition transition: worldwide obesity dynamics and their determinants. *International Journal of Obesity and Related Metabolic Disorders* 28 (Suppl 3):S2–S9.
37. Popkin BM. (2004). The nutrition transition: an overview of world patterns of change. *Nutrition Review* 62(7 Pt 2): S140–S143.