

Prevalence and associated factors of stunting and thinness among children and adolescents in Nasarawa State: comparison with World Health Organization reference

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ABSTRACT

INTRODUCTION: Nutritional status and growth patterns are key indicators of a population's socioeconomic well-being, but data on the prevalence of undernutrition and percentile ranges for height, weight, and body mass index (BMI) of children and adolescents in Nigeria are currently lacking. This study aimed to determine how common undernutrition is and generate reference percentile ranges for height, weight, and BMI.

METHODS: The height and weight of 1,541 boys and 1,650 girls aged 5–18 years from Lafia, Nasarawa State, Nigeria, were measured in 2018 – 2019. The LMS method was used to generate smoothed percentiles of height, weight and BMI-for-age. Classifications of nutritional status were made according to World Health Organization (WHO) recommendations for stunting and thinness.

RESULTS: The proportions of moderately and severely stunted boys were 17.8% and 5.6%, respectively, while the proportions of moderately and severely thinned boys were 52.4% and 27.5%. In girls, moderate and severe stunting incidence was 10.9% and 3.2%, respectively, whereas moderate and severe thinness prevalence was 43.7% and 18.8%, respectively.

CONCLUSION: The present study shows that undernutrition is highly prevalent among children and adolescents in Lafia, although the severity of undernutrition is higher in boys than girls. This study offers researchers in Nigeria or other low- and middle-income nations the most recent age- and sex-standardized percentiles for height, weight, and BMI of children and adolescents in Lafia that may be used for comparison.

Keywords: Lafia, Undernutrition, Children, Stunting, Thinness

INTRODUCTION

Anthropometric parameters are important for growth monitoring and are indicators of the nutritional status of children and adolescents.

Anthropometry is the most practical, useful, and common tool for identifying nutritional status in clinical and field settings, especially in developing countries. Despite its usefulness, there are disagreements regarding adopting international

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cut-off points for anthropometric measures to detect growth patterns and nutritional status. The disagreements over the cut-offs stem from the importance, applicability, and biological definition of cut-off points for different populations resident in different geographic locations [1–3]. Despite this, because anthropometric measurements offer additional insights into critical areas of human growth, nutrition, and adaptation to challenging environmental conditions, they are still regarded as the most efficient and valuable way to screen physical growth and assess nutritional needs in nutritional anthropometry [4].

The pros and cons of small body size in developing countries have been studied as issues affecting productivity and health [2]. Reduced body size and lower muscle mass have been associated with undernutrition and are viewed as limiting factors to human productivity because evidence from studies comparing malnourished and well-nourished children has provided support for the hypothesis that those with bigger body sizes are at an advantage. There has been renewed debate on whether interventions in adolescence could compensate for both linear growth deficits [5, 6] and cognitive achievements [7–9] earlier in life. Adolescence, usually defined as a subpopulation aged 10 – 19 years old [9, 10], is a stage characterized by rapid growth that is similar only to that at the first 1000 days (i.e., 280 days in utero plus 2 years of postnatal life) of life and presents an opportunity for accelerated growth [6, 11], and increased maternal height is expected to lead to improved outcomes in children [8]. Furthermore, women who were born stunted and remained stunted into adulthood are more likely to give birth to stunted children as well [12]. For instance, a study reported that children born by mothers with height deficits as adults were approximately 15% more likely to experience height deficits in childhood and were more likely to remain so through early adolescence than their counterparts whose mothers were not stunted [13].

Stunting (linear growth retardation) – generally defined as height-for-age z-score <-2 is a reflection of poor growth and development, is common in many developing countries, and has become a major public health problem [12]. Growth failure often begins in utero and continues for at least the first 2 years of postnatal life. Most studies on biological anthropology have widely stated that

the first 1000 days are the most critical window of opportunity for nutritional interventions and that later recovery is not possible [12]. While there is some validity to this claim, evidence has provided support that this is far from absolute in that catch-up growth following growth faltering in infancy can occur in childhood and adolescence [7,8,14,15]. For example, large surveys in low- and middle-income countries show that children who were height-deficient in childhood recovered from stuntedness in adolescence. Although there is evidence that nutritional interventions beyond infancy led to nutritional improvement, this impact is rather smaller compared to interventions made during infancy [16]. Evidence linking improved nutrition beyond the first 1000 days and cognitive achievements has produced variable results [7-9,13,16]. Although evidence from some of the studies suggests improved cognitive achievement following nutritional intervention beyond the first 1000 days of life, studies examining the association between accelerated growth beyond the first 1000 days of life and cognitive achievement may deserve attention.

Nevertheless, the growth patterns and nutritional status of children and adolescents aged 5 - 18 years old in Nigeria remain unknown. Growth and nutritional status in these populations have not been evaluated, probably because they have not been seen as a priority issue by health authorities or due to their cost implications to generate using a traditional extemporaneous cross-sectional study. Moreover, presently available information on the growth and nutritional status of children and adolescents in Nigeria is inconsistent and remains unclear [17-20]. However, evidence demonstrating undernutrition in children and adolescents as a major public health problem in Nigeria is mounting [21-23].

To ascertain the nutritional status and growth pattern of children and adolescents in Lafia, we collected population-based data to estimate the prevalence of stunting and thinness among children and adolescents aged 5 – 18 years. We also generated reference ranges for height, weight, and BMI from the same individuals' reference ranges for use in growth and nutritional status assessments. Finally, we generated summary values of LMS parameters that allow for the calculation of respective z-scores standardized for age and sex category.

METHODS

Participants

The subjects of the study are children and adolescents from Lafia, the capital city of Nasarawa State, in north-central Nigeria. The region is served by a relatively stable electricity supply. However, households provide water for themselves through the sinking of boreholes and wells. Sanitation and road networks are poor. The population of Lafia was estimated at 330,712 (NPC, 2006). Lafia is predominantly occupied by the Eggon, Migili, Alago, and Kanuri ethnic groups. Modern Lafia is an administrative centre and a centre of education.

Data Collection

Data was collected between 2018 and 2019 by the principal investigator, MN, along with a female research assistant who received training in anthropometric procedures before data collection. A test-retest reliability study was conducted, and intraclass correlation coefficients for all anthropometric variables examined ranged from 0.91 to 0.98. MN took all of the measurements for the boys, whereas the female research assistant took all of the measurements for the girls to ensure that there was little error amongst observers. The present cross-sectional study used a multistage simple random sampling technique and included 3,191 subjects (1,541 boys; 1,650 girls) aged 5–18 years, attending primary and secondary schools. All participants attended schools for primary or secondary education in Lafia. The purpose and procedure of the study were fully explained to the authorities of participating schools and parents or caregivers. Subjects were recruited after their parents or caregivers signed informed written consent to participate in the study. The exact date of birth of each child was reported by the child's parent or caregiver. The chronological age of each subject was calculated by subtracting the date of birth from the date of investigation using the Statistical Product and Service Solutions (IBM SPSS Statistics for Windows, Version 27.0. Armonk, NY: IBM Corp) date and time wizard expressed in months.

Anthropometric Measurements

Height was measured in cm with a portable stadiometer with the subject standing straight and the head positioned in the Frankfort plane to the nearest 0.1 cm. Weight was recorded in kg with a portable digital scale, with the participant

standing at the central part of the scale platform, bear-footed, while wearing minimal clothing to the nearest 0.1 kg. The BMI was calculated as $(\text{weight (kg)})/(\text{height (m)})^2$.

Nutritional Status

Classification into nutritional status was made according to the WHO 2007 SPSS macro [24]. The macro generates the prevalence and z-score for children and adolescents aged 5 to 19 years. Malnutrition, defined as “an abnormal physiological state caused by deficiencies, surpluses, or imbalances in protein, energy, and/or other required nutrients” [25], was evaluated with the following anthropometric indices: Height-for-age (HAZ) and BMI-for-age (BAZ). The HAZ and BAZ were standardized as z-scores for each age and sex based on the WHO 2007 growth reference percentiles. HAZ <-2 SD was used to classify moderate stunting or linear growth faltering, whereas HAZ <-3 SD was used to classify severe linear growth faltering (severe stunting).

The HAZ was employed as a long-term nutritional status indicator [4, 26]. BAZ was also employed as a short-term nutritional status measure. Those with a BAZ of <-2 SD were considered thin, while those with a BAZ of <-3 SD were considered severely thin. The 3rd, 50th, and 97th percentiles of height and BMI of children and adolescents from Lafia were compared to the corresponding WHO 2007 reference data.

Estimation of Centiles

For each chart, the LMS approach was used to determine centiles. This method fits changes in height, weight, and BMI across age and sex groups as a function of three curves: 1) L indicates the Box-Cox power required to remove skewness; 2) M represents the median; and 3) S represents the coefficient of variation. The three curves were fitted as cubic splines using penalized likelihood, and the amount of smoothing required was given as equivalent degrees of freedom (EDF) for L, M, and S, with EDF for M > EDF for S > EDF for L. Visual, z-scores to verify outlying values, the Q test for goodness of fit, and detrended quantile-quantile (Q-Q) plots [27] for the global goodness of fit were all performed to investigate the fit of the new model.

Age- and sex-specific charts depicting the 3rd, 10th, 25th, 50th, 75th, 90th, and 97th centiles for height, weight, and BMI were obtained.

Comparison to WHO 2007 Growth Reference

To compare the growth and nutritional status of Nigerian children and adolescents, we compared our centiles for height and BMI to those of WHO. The WHO (2007) height and BMI centiles tabulated for children and adolescents aged 5–19 years were processed using GraphPad Prism version 8.4.3, and the resultant smoothed curves for the 3rd, 50th, and 97th centiles were used for comparison. Centile estimation was conducted with LMSchartmaker Pro version 2.54 [28].

The study protocol was reviewed and approved by the Ahmadu Bello University Ethics Committee on the Use of Human Subjects in Research, and an approval number (ABUCUHSR/2018/004) was given to the study. Written permission was also obtained from Lafia Local Government Education Authority, the authorities of participating schools, and the parents of children less than 18 years old.

RESULTS

The descriptive statistics for height, weight, and BMI are shown in Table 1. The mean height, weight, and BMI for both sexes increased significantly with age, as expected. Boys have a significantly larger mean height at the ages of 9, 17, and 18, whereas girls have a higher BMI at the ages of 9–14 and 16

and 17. Sex differences in height were small from age 5–8 years. The mean values of weight were significantly higher in girls at ages 12 and 14 and significantly higher in boys in late adolescence.

The prevalence (%) of stunting (severe stunting, moderate stunting and normal height based on <-3, <-2, and +1 z-score of height-for-age) for the overall population and specific to age and sex is presented in Table 2. Compared to WHO (2007), boys showed a significantly lower mean z-score for height-for-age than girls (boys = -0.80 ± 1.47; girls = -0.57 ± 1.26; *t* = 4.83; *P* < 0.001). The mean z-score of height-for-age for the combined population is still lower than that of the WHO (2007) (z-score = -0.68 ± 1.37). Except for age 5 years, both boys and girls showed negative mean z-scores for height-for-age in all age bands. Boys showed a significantly higher prevalence of severe stunting than girls (boys = 5.6%; girls = 3.2%; $\chi^2 = 11.25$, *P* < 0.001). Boys also showed a significantly higher prevalence of moderate stunting than girls (boys = 17.8%; girls = 10.9%; $\chi^2 = 31.36$, *P* < 0.001). The total prevalence of severe and moderate stunting was 4.4% and 14.3%, respectively. The prevalence of severe and moderate stunting reached a plateau at 15 years for boys and 14 years for girls. The severity and moderate stunting ranges in boys (0.0–20.6%

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

Age	n	Boys (n = 1,541)			Girls (n = 1,650)		
		Height (cm) Mean ± SD	Weight (kg) Mean ± SD	BMI (kgm ⁻²) Mean ± SD	Height (cm) Mean ± SD	Weight (kg) Mean ± SD	BMI (kgm ⁻²) Mean ± SD
5	70	114.32 ± 9.09	17.54 ± 2.78	13.48 ± 2.11	110.84 ± 4.83	16.43 ± 2.18	13.37 ± 1.47
6	260	116.08 ± 7.71	17.95 ± 2.60	13.30 ± 1.31	116.00 ± 10.30	18.66 ± 5.94	13.75 ± 2.39
7	103	120.11 ± 11.20	19.77 ± 4.59	13.75 ± 2.50	119.95 ± 9.13	19.05 ± 2.27	13.34 ± 1.85
8	211	125.11 ± 6.14	20.78 ± 2.10	13.31 ± 1.37	124.97 ± 7.08	20.42 ± 3.10	13.06 ± 1.56
9	264	130.90 ± 7.97	21.85 ± 3.44	12.73 ± 1.44	128.64 ± 6.71	22.04 ± 3.50	13.30 ± 1.68
10	246	134.20 ± 9.08	24.44 ± 4.40	13.53 ± 1.70	135.00 ± 8.09	23.53 ± 3.79	12.87 ± 1.38
11	283	137.71 ± 8.03	26.45 ± 4.64	13.89 ± 1.74	139.37 ± 8.12	26.97 ± 5.71	13.79 ± 1.90
12	219	143.42 ± 9.58	28.44 ± 5.28	13.82 ± 1.89	144.36 ± 10.01	30.58 ± 6.65	14.53 ± 1.76
13	295	151.06 ± 12.08	36.21 ± 10.87	15.53 ± 2.48	150.61 ± 9.36	36.94 ± 8.19	16.18 ± 2.72
14	293	151.19 ± 10.54	35.15 ± 8.51	15.15 ± 1.86	153.21 ± 8.88	37.56 ± 8.39	15.86 ± 2.55
15	325	153.87 ± 9.53	36.89 ± 7.01	15.47 ± 1.88	156.75 ± 8.61	40.71 ± 7.37	16.48 ± 2.25
16	263	161.33 ± 10.74	43.40 ± 8.93	16.51 ± 2.02	159.78 ± 6.75	44.09 ± 8.24	17.22 ± 2.78
17	206	166.01 ± 9.51	46.73 ± 8.58	16.81 ± 1.74	161.28 ± 6.08	47.34 ± 7.59	18.19 ± 2.75
18	153	169.05 ± 8.44	50.43 ± 7.88	17.55 ± 1.85	159.57 ± 8.18	48.49 ± 8.26	18.17 ± 2.64

SD: Standard deviation

Table 1: Mean ± SD (95% CI) height-for-age z-scores and distribution of the nutritional status of Nigerian children and adolescents stratified by age and sex (severe, moderate, and normal height based on <-3 z and <-2 z and > +1 z-scores, respectively)

Age	Combined population						Boys						Girls					
	HAZ	Mean ± SD	95% CI	SS (%)	MS (%)	NH (%)	HAZ	Mean ± SD	95% CI	SS (%)	MS (%)	NH (%)	HAZ	Mean ± SD	95% CI	SS (%)	MS (%)	NH (%)
5		0.61 ± 1.66	(0.23, 1.00)	1.4	1.4	35.7		0.88 ± 1.98	(0.27, 1.49)	2.5	2.5	47.5		0.26 ± 1.01	(-0.10, 0.62)	0.0	0.0	20.0
6		0.06 ± 1.38	(-0.23, 0.11)	0.0	6.5	19.6		-0.03 ± 1.44	(-0.29, 0.22)	0.0	6.5	24.4		0.09 ± 1.32	(-0.31, 0.13)	0.0	6.6	15.3
7		0.33 ± 1.58	(-0.63, -0.02)	2.9	7.8	21.4		-0.53 ± 1.45	(-0.95, -0.12)	2.1	8.5	17.0		0.16 ± 1.67	(-0.59, 0.28)	3.6	7.1	25.0
8		0.34 ± 1.13	(-0.50, -0.19)	0.0	6.2	10.4		-0.38 ± 1.09	(-0.57, -0.20)	0.0	6.6	8.8		0.27 ± 1.22	(-0.55, 0.00)	0.0	5.3	13.3
9		0.42 ± 1.25	(-0.57, -0.27)	0.8	8.3	12.9		-0.28 ± 1.33	(-0.49, -0.07)	0.6	7.1	14.9		0.63 ± 1.10	(-0.84, -0.43)	0.9	10.0	10.0
10		0.57 ± 1.34	(-0.73, -0.40)	1.2	9.8	11.8		-0.56 ± 1.43	(-0.82, -0.31)	1.7	9.2	14.2		0.57 ± 1.27	(-0.79, -0.31)	0.8	10.3	9.5
11		0.82 ± 1.21	(-0.97, -0.68)	4.2	12.7	7.8		-0.80 ± 1.19	(-1.00, -0.61)	4.3	11.4	7.1		0.85 ± 1.22	(-1.05, -0.65)	4.2	14.0	8.4
12		0.89 ± 1.41	(-1.08, -0.71)	6.8	15.1	6.8		-0.80 ± 1.35	(-1.04, -0.55)	4.2	11.0	7.6		1.00 ± 1.46	(-1.29, -0.72)	9.9	19.8	5.9
13		0.76 ± 1.47	(-0.93, -0.59)	4.1	18.0	11.9		-0.67 ± 1.63	(-0.95, -0.39)	2.4	18.9	16.5		0.83 ± 1.35	(-1.03, -0.63)	5.4	17.3	8.3
14		1.22 ± 1.35	(-1.37, -1.06)	9.9	29.0	6.1		-1.56 ± 1.37	(-1.79, -1.32)	14.0	41.1	7.8		0.95 ± 1.28	(-1.14, -0.75)	6.7	19.5	4.9
15		1.23 ± 1.35	(-1.37, -1.08)	11.1	27.7	3.7		-1.93 ± 1.22	(-2.13, -1.73)	20.6	46.8	0.0		0.68 ± 1.18	(-0.85, -0.51)	3.8	13.0	6.5
16		0.77 ± 1.14	(-0.91, -0.63)	4.2	15.2	3.8		-1.40 ± 1.23	(-1.63, -1.16)	9.7	35.0	2.9		0.36 ± 0.86	(-0.50, -0.23)	0.6	2.5	4.4
17		0.62 ± 1.16	(-0.78, -0.47)	3.9	9.2	3.9		-1.20 ± 1.24	(-1.46, -0.93)	8.4	18.1	2.4		0.24 ± 0.91	(-0.40, -0.07)	0.8	3.3	4.9
18		0.75 ± 1.20	(-0.94, -0.56)	5.2	9.2	6.5		-0.95 ± 1.13	(-1.20, -0.70)	5.0	10.0	5.0		0.53 ± 1.24	(-0.81, -0.24)	5.5	8.2	8.2

HAZ: height-for-age z-score; SS: severely stunted; MS: moderately stunted; NH: normal height

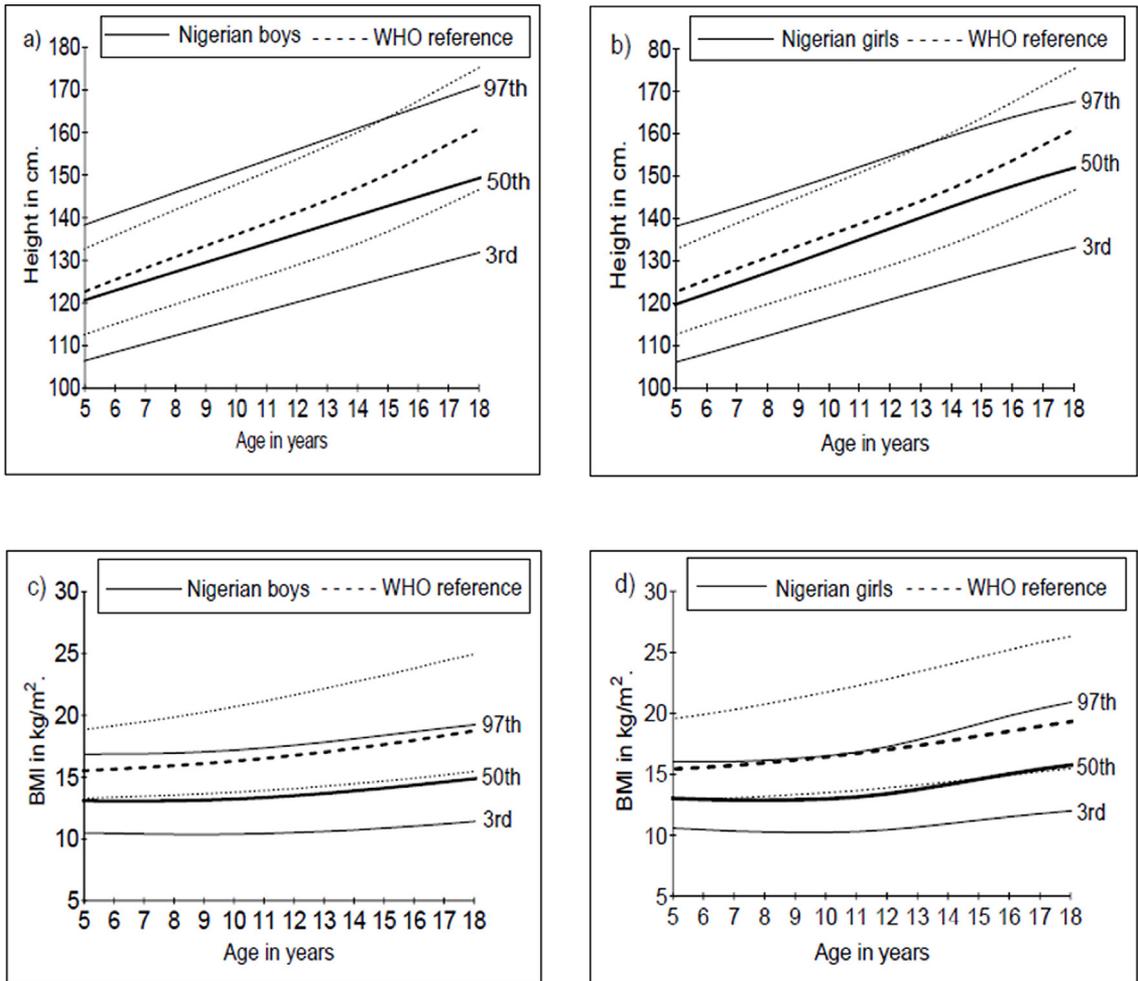


Figure 1: Height-for-age (a, b) and BMI-for-age (c, d) percentiles of boys and girls from Nigeria (solid lines) compared to WHO (2007) reference data (dashed lines).

and 2.5 – 46.8%) and girls (0.0 – 9.9% and 0.0 – 19.8%), respectively. A sex-wise comparison of moderate and severe stunting revealed that boys are two times more likely to be stunted than girls. Stunting was higher among adolescents than non-adolescents in both sexes and tends to decrease in late adolescence.

Table 3 provides the prevalence (%) of thinness (severe and moderate based on <-3 and <-2 z-score of BMI-for-age) stratified by age group for the overall population and based on sex. The prevalence of moderate and severe thinness in the overall population was 47.8% and 23.0%, respectively. Compared to WHO (2007), boys showed a significantly lower mean z-score for BMI-for-age than girls (boys = -2.16 ± 1.31; girls = -1.75 ± 1.31; t = 8.70; P < 0.001). Boys showed a significantly

higher prevalence of moderate thinness than girls (boys = 52.4%; girls = 43.7%; $\chi^2 = 24.02$; P < 0.001). The prevalence of severe thinness was also significantly higher in boys than in girls (boys = 27.5%; girls = 18.8%; $\chi^2 = 33.48$; P < 0.001). As expected with the high prevalence of thinness, the prevalence of overweight was 1.1% for the combined population, 0.5% for boys, and 1.7% for girls, and it showed a significant association with sex ($\chi^2 = 10.94$; P < 0.001). The prevalence of boys and girls who were simultaneously thin and stunted was 10.9% and 6.4%, respectively. Only 7 boys and 28 girls were identified as overweight. Therefore, these children were excluded from further analysis.

Tables 4–6 document the smoothed percentile distributions (3rd, 10th, 25th, 50th, 75th, 90th and 97th). Graphical comparisons of the new growth



Table 3: Mean ± SD (95% CI) BMI-for-age z-scores and prevalence (%) of undernourished Nigerian children and adolescents stratified by age and sex (severe thinness and moderate thinness based on <-3 z and <-2 z scores, respectively)

Age	Combined population											
	Boys						Girls					
	BAZ	Mean ± SD	95% CI	ST (%)	MT (%)	< 3	BAZ	Mean ± SD	95% CI	ST (%)	MT (%)	< 3
5	1.60 ± 1.54	(-1.96,-1.23)	20.3	34.8	1.63 ± 1.72	(-2.17,-1.09)	20.5	33.3	1.55 ± 1.28	(-2.01,-1.09)	20.0	36.7
6	1.51 ± 1.43	(-1.69,-1.34)	14.9	35.1	1.80 ± 1.21	(-2.01,-1.58)	17.9	43.1	1.27 ± 1.57	(-1.53,-1.01)	12.2	28.1
7	1.73 ± 1.36	(-2.00,-1.47)	20.4	40.8	1.83 ± 1.38	(-2.22,-1.43)	21.3	42.6	1.65 ± 1.34	(-2.00,-1.30)	19.6	39.3
8	2.02 ± 1.24	(-2.19,-1.85)	21.6	48.1	2.10 ± 1.29	(-2.31,-1.88)	26.7	48.9	1.88 ± 1.14	(-2.15,-1.62)	12.3	46.6
9	2.38 ± 1.32	(-2.55,-2.22)	33.3	59.9	2.68 ± 1.31	(-2.89,-2.46)	40.6	64.3	2.00 ± 1.25	(-2.24,-1.76)	23.9	54.1
10	2.34 ± 1.17	(-2.49,-2.19)	29.2	65.7	2.10 ± 1.23	(-2.33,-1.88)	24.1	58.9	2.56 ± 1.08	(-2.75,-2.37)	33.9	71.8
11	2.20 ± 1.26	(-2.35,-2.05)	30.0	57.8	2.26 ± 1.34	(-2.48,-2.03)	35.0	55.5	2.15 ± 1.18	(-2.34,-1.95)	25.0	60.0
12	2.22 ± 1.24	(-1.71,-2.05)	25.4	56.9	2.45 ± 1.34	(-2.70,-2.20)	34.5	59.1	1.97 ± 1.07	(-2.18,-1.76)	15.2	54.5
13	1.55 ± 1.42	(-2.20,-1.38)	17.4	40.3	1.66 ± 1.48	(-1.93,-1.40)	19.8	43.8	1.46 ± 1.38	(-1.67,-1.25)	15.6	37.7
14	2.11 ± 1.34	(-2.26,-1.96)	29.7	54.5	2.33 ± 1.25	(-2.55,-2.12)	33.9	56.7	1.94 ± 1.39	(-2.15,-1.72)	26.4	52.8
15	2.06 ± 1.24	(-2.20,-1.93)	24.8	50.9	2.44 ± 1.22	(-2.64,-2.23)	34.8	62.3	1.78 ± 1.19	(-1.95,-1.61)	17.4	42.4
16	1.79 ± 1.29	(-1.94,-1.63)	20.5	39.5	2.13 ± 1.24	(-2.37,-1.89)	23.8	49.5	1.56 ± 1.27	(-1.76,-1.36)	18.4	32.9
17	1.62 ± 1.18	(-1.78,-1.46)	13.1	34.5	2.16 ± 1.03	(-2.39,-1.94)	18.1	50.6	1.25 ± 1.14	(-1.45,-1.05)	9.8	23.6
18	1.58 ± 1.05	(-1.75,-1.42)	9.9	29.1	1.84 ± 0.86	(-2.03,-1.65)	12.8	37.2	1.31 ± 1.17	(-1.58,-1.04)	6.8	20.5
Total	1.94 ± 1.32	(-1.99,-1.90)	23.0	47.8	2.16 ± 1.31	(-2.22,-2.09)	27.5	52.4	1.75 ± 1.31	(-1.81,-1.69)	18.8	43.7

BAZ, BMI-for-age z-score; ST, severe thinness; MT, moderate thinness

Table 4: Smoothed percentiles for height-for-age and LMS parameters

Age, Y	Boys										Girls									
	L	S	3 ^d	10 th	25 th	M	75 th	90 th	97 th	L	S	3 ^d	10 th	25 th	M	75 th	90 th	97 th		
5.00 – 5.49	1	0.0655	98.68	102.78	107.18	111.8950	116.97	122.43	128.34	1	0.0875	95.23	99.52	104.50	110.3943	117.52	126.38	137.84		
5.50 – 5.99	1	0.0655	100.61	104.80	109.28	114.0837	119.25	124.82	130.83	1	0.0858	97.51	101.83	106.85	112.7596	119.88	128.69	140.02		
6.00 – 6.49	1	0.0654	102.56	106.82	111.38	116.2759	121.54	127.21	133.33	1	0.0841	99.80	104.16	109.20	115.1225	122.23	130.99	142.17		
6.50 – 6.99	1	0.0654	104.50	108.84	113.49	118.4746	123.83	129.61	135.84	1	0.0824	102.10	106.48	111.55	117.4816	124.58	133.27	144.30		
7.00 – 7.49	1	0.0654	106.46	110.88	115.61	120.6806	126.14	132.01	138.36	1	0.0807	104.40	108.82	113.90	119.8396	126.91	135.54	146.41		
7.50 – 7.99	1	0.0653	108.42	112.91	117.73	122.8931	128.44	134.43	140.88	1	0.0790	106.73	111.17	116.26	122.2000	129.25	137.80	148.51		
8.00 – 8.49	1	0.0653	110.38	114.96	119.86	125.1096	130.76	136.84	143.41	1	0.0773	109.07	113.53	118.63	124.5652	131.58	140.05	150.59		
8.50 – 8.99	1	0.0652	112.35	117.00	121.98	127.3266	133.07	139.26	145.94	1	0.0756	111.43	115.90	121.01	126.9365	133.91	142.30	152.67		
9.00 – 9.49	1	0.0652	114.31	119.04	124.11	129.5403	135.38	141.67	148.46	1	0.0739	113.80	118.29	123.41	129.3133	136.25	144.54	154.74		
9.50 – 9.99	1	0.0651	116.27	121.08	126.23	131.7479	137.68	144.07	150.97	1	0.0722	116.19	120.69	125.80	131.6926	138.58	146.78	156.79		
10.00 – 10.49	1	0.0651	118.22	123.11	128.34	133.9505	139.98	146.47	153.48	1	0.0705	118.59	123.10	128.20	134.0658	140.89	148.99	158.82		
10.50 – 10.99	1	0.0651	120.17	125.14	130.45	136.1500	142.27	148.87	155.99	1	0.0688	120.99	125.49	130.59	136.4222	143.19	151.18	160.82		
11.00 – 11.49	1	0.0650	122.12	127.16	132.56	138.3478	144.57	151.26	158.49	1	0.0671	123.38	127.88	132.96	138.7504	145.45	153.32	162.77		
11.50 – 11.99	1	0.0650	124.07	129.19	134.67	140.5441	146.86	153.66	160.99	1	0.0654	125.74	130.23	135.29	141.0383	147.66	155.41	164.65		
12.00 – 12.49	1	0.0649	126.02	131.21	136.77	142.7359	149.14	156.04	163.49	1	0.0637	128.07	132.55	137.57	143.2715	149.81	157.43	166.46		
12.50 – 12.99	1	0.0649	127.95	133.23	138.87	144.9196	151.42	158.42	165.97	1	0.0620	130.35	134.80	139.79	145.4357	151.89	159.36	168.18		
13.00 – 13.49	1	0.0648	129.88	135.23	140.95	147.0918	153.69	160.78	168.44	1	0.0603	132.57	137.00	141.94	147.5176	153.87	161.20	169.79		
13.50 – 13.99	1	0.0648	131.80	137.22	143.03	149.2512	155.94	163.13	170.90	1	0.0586	134.72	139.11	144.01	149.5064	155.75	162.92	171.29		
14.00 – 14.49	1	0.0647	133.71	139.21	145.10	151.4043	158.18	165.48	173.35	1	0.0569	136.79	141.15	145.98	151.4005	157.53	164.54	172.66		
14.50 – 14.99	1	0.0647	135.63	141.20	147.16	153.5589	160.43	167.82	175.80	1	0.0552	138.79	143.10	147.87	153.2014	159.20	166.04	173.93		
15.00 – 15.49	1	0.0647	137.55	143.20	149.24	155.7209	162.68	170.17	178.26	1	0.0535	140.73	144.98	149.68	154.9146	160.79	167.44	175.09		
15.49 – 15.99	1	0.0646	139.48	145.20	151.33	157.8938	164.95	172.54	180.73	1	0.0518	142.61	146.80	151.42	156.5476	162.28	168.76	176.15		
16.00 – 16.49	1	0.0646	141.42	147.22	153.42	160.0754	167.22	174.91	183.21	1	0.0501	144.43	148.56	153.10	158.1121	163.70	169.99	177.13		
16.50 – 16.99	1	0.0645	143.36	149.24	155.52	162.2618	169.50	177.29	185.69	1	0.0484	146.22	150.27	154.72	159.6218	165.06	171.16	178.04		
17.00 – 17.49	1	0.0645	145.31	151.26	157.63	164.4506	171.78	179.67	188.18	1	0.0467	147.98	151.96	156.31	161.0919	166.38	172.28	178.90		
17.50 – 17.99	1	0.0644	147.25	153.28	159.73	166.6396	174.06	182.05	190.66	1	0.0450	149.73	153.63	157.88	162.5375	167.67	173.37	179.74		
18.00 – 18.49	1	0.0644	149.20	155.30	161.83	168.8287	176.34	184.43	193.15	1	0.0434	151.48	155.30	159.44	163.9713	168.94	174.44	180.56		

The LMSChartmaker was used to calculate all estimates, L denotes box power to remove skewness, M denotes the median, and S_i the coefficient of variation. The LMS parameters can be used to calculate the z score of the completed height of a child or adolescent with the help of the formula: [(height + M)_i - J] ÷ S × L that approximate to the nearest completed 6-months of age



Table 5: Smoothed percentiles for weight-for-age and LMS parameters

Age, Y	Boy										Girls									
	L	S	3 rd	10 th	25 th	M	75 th	90 th	97 th	L	S	3 rd	10 th	25 th	M	75 th	90 th	97 th		
5.00 – 5.49	-0.9974	0.1343	13.03	14.02	15.17	16.5303	18.16	20.13	22.60	-1.9906	0.1217	13.01	13.78	14.71	15.8637	17.33	19.30	22.13		
5.50 – 5.99	-0.9503	0.1365	13.43	14.47	15.69	17.1197	18.83	20.91	23.48	-1.8713	0.1263	13.61	14.46	15.48	16.7362	18.34	20.49	23.56		
6.00 – 6.49	-0.9033	0.1388	13.84	14.94	16.22	17.7235	19.52	21.70	24.40	-1.7519	0.1310	14.15	15.07	16.18	17.5498	19.29	21.62	24.92		
6.50 – 6.99	-0.8562	0.1412	14.25	15.41	16.76	18.3534	20.25	22.54	25.36	-1.6325	0.1357	14.58	15.58	16.78	18.2573	20.13	22.62	26.13		
7.00 – 7.49	-0.8091	0.1439	14.68	15.90	17.33	19.0109	21.01	23.42	26.38	-1.5129	0.1405	14.92	15.99	17.28	18.8581	20.86	23.50	27.19		
7.50 – 7.99	-0.7620	0.1471	15.10	16.41	17.92	19.6956	21.81	24.36	27.48	-1.3931	0.1454	15.18	16.32	17.69	19.3759	21.50	24.29	28.13		
8.00 – 8.49	-0.7150	0.1508	15.53	16.92	18.52	20.4120	22.66	25.36	28.67	-1.2730	0.1503	15.41	16.63	18.09	19.8830	22.13	25.06	29.05		
8.50 – 8.99	-0.6679	0.1551	15.97	17.44	19.15	21.1689	23.56	26.45	29.97	-1.1524	0.1553	15.69	17.00	18.56	20.4668	22.85	25.93	30.07		
9.00 – 9.49	-0.6208	0.1601	16.42	18.00	19.83	21.9902	24.56	27.65	31.42	-1.0313	0.1603	16.09	17.50	19.18	21.2240	23.77	27.02	31.32		
9.50 – 9.99	-0.5737	0.1655	16.91	18.60	20.58	22.8984	25.66	28.99	33.05	-0.9096	0.1651	16.66	18.19	20.02	22.2331	24.97	28.42	32.92		
10.00 – 10.49	-0.5266	0.1712	17.44	19.26	21.39	23.8980	26.88	30.48	34.86	-0.7872	0.1697	17.39	19.07	21.08	23.4903	26.45	30.14	34.87		
10.50 – 10.99	-0.4796	0.1770	18.02	19.98	22.28	24.9885	28.22	32.10	36.83	-0.6640	0.1741	18.26	20.13	22.34	24.9809	28.19	32.15	37.12		
11.00 – 11.49	-0.4325	0.1828	18.64	20.76	23.24	26.1690	29.66	33.86	38.96	-0.5401	0.1782	19.29	21.37	23.82	26.7286	30.22	34.47	39.71		
11.50 – 11.99	-0.3854	0.1884	19.30	21.59	24.27	27.4371	31.21	35.73	41.23	-0.4153	0.1818	20.48	22.81	25.53	28.7347	32.54	37.10	42.62		
12.00 – 12.49	-0.3383	0.1937	20.00	22.47	25.37	28.7858	32.85	37.72	43.61	-0.2898	0.1848	21.73	24.33	27.35	30.8725	35.00	39.87	45.64		
12.50 – 12.99	-0.2913	0.1986	20.74	23.40	26.53	30.2046	34.57	39.79	46.06	-0.1637	0.1871	22.94	25.83	29.16	32.9905	37.42	42.56	48.54		
13.00 – 13.49	-0.2442	0.2027	21.52	24.38	27.73	31.6746	36.34	41.89	48.54	-0.0369	0.1887	24.03	27.22	30.84	34.9665	39.67	45.03	51.14		
13.50 – 13.99	-0.1971	0.2059	22.33	25.39	28.98	33.1799	38.14	44.00	50.98	0.0902	0.1895	24.96	28.43	32.33	36.7128	41.63	47.13	53.29		
14.00 – 14.49	-0.1500	0.2083	23.18	26.45	30.26	34.7242	39.96	46.12	53.39	0.2177	0.1894	25.76	29.50	33.65	38.2497	43.32	48.91	55.05		
14.50 – 14.99	-0.1029	0.2099	24.08	27.56	31.60	36.3154	41.81	48.24	55.78	0.3453	0.1885	26.47	30.48	34.86	39.6441	44.83	50.45	56.51		
15.00 – 15.49	-0.0559	0.2108	25.02	28.72	33.00	37.9564	43.71	50.39	58.16	0.4729	0.1869	27.20	31.48	36.09	41.0408	46.32	51.95	57.91		
15.49 – 15.99	-0.0088	0.2112	26.01	29.93	34.44	39.6465	45.64	52.56	60.53	0.6006	0.1848	28.01	32.58	37.43	42.5406	47.91	53.53	59.40		
16.00 – 16.49	0.0383	0.2111	27.03	31.18	35.93	41.3745	47.61	54.74	62.90	0.7284	0.1824	28.79	33.66	38.73	43.9906	49.43	55.03	60.79		
16.50 – 16.99	0.0854	0.2107	28.08	32.45	37.44	43.1272	49.59	56.93	65.25	0.8563	0.1797	29.41	34.57	39.83	45.2006	50.66	56.21	61.84		
17.00 – 17.49	0.1325	0.2101	29.14	33.75	38.98	44.8956	51.58	59.11	67.57	0.9842	0.1770	29.82	35.23	40.65	46.0847	51.53	56.98	62.44		
17.50 – 17.99	0.1795	0.2093	30.20	35.05	40.52	46.6725	53.57	61.28	69.88	1.1123	0.1742	30.00	35.64	41.17	46.6251	52.01	57.33	62.59		
18.00 – 18.49	0.2266	0.2084	31.27	36.36	42.07	48.4534	55.56	63.44	72.17	1.2403	0.1715	30.05	35.90	41.52	46.9726	52.27	57.45	62.51		

The LMSChartmaker was used to calculate all estimates. L denotes box power to remove skewness, M denotes the median and S_i is the coefficient of variation. The LMS parameters can be used to calculate the z score of the completed weight of a child or adolescent with the help of the formula: [(weight ÷ M)_i - 1] ÷ S × L that is approximate to the nearest completed 6-months of age

charts for height and BMI to the WHO (2007) by using the third, 50th and 97th percentiles are depicted by age and sex in Figure 1. Estimates are calculated at 6-month intervals from 5 to 18 years.

Height-for-Age

For each age and sex, the reference curves for height were modelled with the skewness parameter (L) set to 1 (Table 4). The EDF for the median was set to 3 and for the coefficient of variation to 2. When comparing the new growth charts for height to the WHO (2007) growth charts, differences were noted (Figures 1a and b). The third and 50th percentiles of the new height percentile curves for both boys and girls were symmetrically below those of the WHO (2007) curve across all ages. The 97th percentile of the new height curve was slightly above the WHO (2007) curve from age 5–14 years for both sexes. The third centile curve of the Nigerian boys was on average 11 cm below the WHO (2007) curve, whereas the median centile curve of the Nigerian boys was, on average, 7 cm below the WHO (2007) curve. In contrast, the 97th centile curve of the Nigerian boys was distinctly above the corresponding WHO (2007) curve by an average of 5 cm from age 5 to 12 years. The new height growth chart's 3rd and 50th percentiles lined up with the WHO (2007) chart's corresponding centiles. For Nigerian girls, the 3rd percentile was, on average, 11 cm below the corresponding centile of the WHO (2007) curve. Similarly, the 50th percentile was, on average, 7 cm below the WHO (2007) curve. However, a comparison of the 97th percentile curves showed that Nigerian girls were on average 4 cm above the WHO (2007) from age 5 to 11 years.

Weight-for-Age

The age- and sex-specific weight percentiles and the corresponding LMS parameters are presented in Table 5. The percentiles describe the expected patterns of weight trajectory with age and the sex patterns in boys and girls. In both boys and girls, the weight percentiles were constructed with the EDF for skewness set to 2, while the EDF for coefficient of variation was set to 3. The EDF for the median was set to 4 and 5 for boys and girls, respectively. During the modeling process, parameters for skewness and variation were kept fixed using default estimations from the first model. We conducted several models in which the EDF of the median curve was varied up to 15, and the best models were finally retained.

BMI-for-Age

The smoothed BMI-for-age and sex-specific percentiles are presented in Table 6. In both boys and girls, the BMI percentiles were constructed with the EDF for skewness set to 2, while the EDF of the coefficient of variation was set to 3. The EDF for the median was set to 4 and 7 for boys and girls, respectively. Clear differences can be observed when the smoothed percentile curves of Nigerian boys and girls are compared to those of WHO (2007) (Figures 1c and 1d). The median BMI for Nigerian boys and girls approximates the 3rd percentile across all ages. The 97th percentiles of Nigerian children are tracked neatly along with the WHO (2007) median across several ages, especially in girls (Figure 1d).

DISCUSSION

Stunting and thinness are major nutritional deficiencies and health problems in developing countries. In this study, the prevalence of thinness was 3 to 6 times the rate of stunting. This finding further highlights the view that malnutrition is still a major health problem affecting children and adolescents in Nigeria and other sub-Saharan African countries. Stunting is caused by a diet that is consistently low in quality and quantity, and it is a good sign of chronic undernutrition. Thinness, on the other hand, is a sign of chronic energy deficiency. Assessing stunting and thinness is important for several reasons. First, they are known to result from poor environmental conditions exacerbated by poor socioeconomic status. Hence, the extent of stunting and thinness is commonly used to determine the level of deprivation that commonly precedes developing nutritional policies and intervention strategies. Second, monitoring and evaluation of recovery from stunting in the form of catch-up growth in infancy or adolescence is an assessment of the effectiveness of the intervention program. Third, the functional performance of adults is significantly associated with their extent of stunting in childhood [29], and women who were stunted earlier in life and remained stunted as adults are more likely to have stunted children [12]. Stunting is also particularly detrimental to females because a woman's stature has been reported to be directly proportional to the width of her pelvis [30]. A narrow pelvis can lead to protracted labour and often damage the newborn. Although undernutrition has decreased in many



Table 6: Smoothed percentiles for BMI-for-age and LMS parameters

Age	Boy										Girls									
	L	S	3 rd	10 th	25 th	M	75 th	90 th	97 th	L	S	3 rd	10 th	25 th	M	75 th	90 th	97 th		
5.00 – 5.49	-0.8215	0.1127	10.70	11.42	12.24	13.1639	14.23	15.45	16.89	0.1051	0.0907	11.05	11.75	12.49	13.2665	14.09	14.96	15.88		
5.50 – 5.99	-0.7663	0.1138	10.66	11.39	12.21	13.1438	14.21	15.44	16.88	0.0885	0.0939	10.96	11.68	12.44	13.2415	14.09	15.00	15.95		
6.00 – 6.49	-0.7112	0.1150	10.61	11.35	12.18	13.1234	14.20	15.44	16.87	0.0718	0.0971	10.85	11.59	12.37	13.1992	14.08	15.01	16.01		
6.50 – 6.99	-0.6561	0.1162	10.55	11.31	12.15	13.1029	14.19	15.43	16.86	0.0552	0.1003	10.73	11.48	12.28	13.1276	14.03	15.00	16.03		
7.00 – 7.49	-0.6010	0.1176	10.50	11.26	12.12	13.0846	14.18	15.43	16.86	0.0387	0.1034	10.59	11.35	12.17	13.0378	13.97	14.96	16.02		
7.50 – 7.99	-0.5457	0.1190	10.45	11.23	12.10	13.0719	14.18	15.43	16.87	0.0223	0.1066	10.46	11.23	12.06	12.9487	13.90	14.92	16.02		
8.00 – 8.49	-0.4905	0.1205	10.41	11.20	12.08	13.0708	14.19	15.45	16.89	0.0060	0.1098	10.35	11.13	11.98	12.8895	13.87	14.92	16.05		
8.50 – 8.99	-0.4353	0.1221	10.38	11.18	12.08	13.0888	14.22	15.50	16.94	-0.0102	0.1130	10.28	11.08	11.95	12.8832	13.89	14.98	16.15		
9.00 – 9.49	-0.3803	0.1237	10.37	11.19	12.11	13.1367	14.29	15.58	17.04	-0.0262	0.1161	10.25	11.07	11.96	12.9185	13.96	15.09	16.31		
9.50 – 9.99	-0.3256	0.1254	10.39	11.24	12.18	13.2233	14.39	15.70	17.18	-0.0419	0.1192	10.25	11.09	12.00	12.9879	14.06	15.23	16.50		
10.00 – 10.49	-0.2711	0.1270	10.44	11.31	12.27	13.3464	14.54	15.87	17.36	-0.0572	0.1222	10.30	11.17	12.11	13.1344	14.25	15.47	16.80		
10.50 – 10.99	-0.2169	0.1284	10.52	11.41	12.40	13.5009	14.72	16.07	17.58	-0.0722	0.1252	10.45	11.35	12.33	13.3977	14.57	15.85	17.25		
11.00 – 11.49	-0.1628	0.1297	10.61	11.54	12.56	13.6827	14.93	16.31	17.83	-0.0869	0.1280	10.68	11.61	12.63	13.7545	14.98	16.34	17.82		
11.50 – 11.99	-0.1089	0.1306	10.73	11.69	12.73	13.8881	15.16	16.56	18.10	-0.1013	0.1306	10.95	11.92	12.99	14.1673	15.46	16.89	18.46		
12.00 – 12.49	-0.0549	0.1313	10.88	11.86	12.93	14.1148	15.41	16.83	18.39	-0.1154	0.1330	11.24	12.25	13.37	14.6036	15.96	17.47	19.13		
12.50 – 12.99	-0.0009	0.1315	11.04	12.05	13.15	14.3595	15.68	17.11	18.68	-0.1291	0.1351	11.52	12.58	13.74	15.0319	16.46	18.04	19.79		
13.00 – 13.49	0.0534	0.1312	11.22	12.26	13.39	14.6134	15.95	17.39	18.96	-0.1423	0.1370	11.78	12.87	14.08	15.4194	16.90	18.56	20.39		
13.50 – 13.99	0.1080	0.1304	11.41	12.48	13.63	14.8687	16.21	17.66	19.23	-0.1549	0.1386	12.00	13.12	14.36	15.7441	17.28	18.99	20.90		
14.00 – 14.49	0.1631	0.1291	11.62	12.70	13.87	15.1263	16.48	17.93	19.48	-0.1671	0.1400	12.19	13.34	14.61	16.0294	17.61	19.38	21.35		
14.50 – 14.99	0.2185	0.1275	11.84	12.94	14.12	15.3895	16.74	18.19	19.73	-0.1790	0.1410	12.39	13.55	14.86	16.3080	17.93	19.75	21.78		
15.00 – 15.49	0.2743	0.1256	12.07	13.19	14.39	15.6603	17.01	18.45	19.97	-0.1906	0.1418	12.60	13.79	15.12	16.6036	18.27	20.13	22.23		
15.49 – 15.99	0.3304	0.1235	12.32	13.46	14.66	15.9400	17.29	18.71	20.21	-0.2021	0.1425	12.83	14.05	15.41	16.9281	18.63	20.55	22.70		
16.00 – 16.49	0.3867	0.1212	12.58	13.73	14.95	16.2261	17.57	18.98	20.46	-0.2134	0.1430	13.07	14.31	15.70	17.2546	19.00	20.96	23.18		
16.50 – 16.99	0.4433	0.1187	12.85	14.02	15.24	16.5157	17.85	19.25	20.70	-0.2246	0.1435	13.29	14.55	15.96	17.5488	19.33	21.34	23.61		
17.00 – 17.49	0.5000	0.1162	13.13	14.30	15.53	16.8079	18.14	19.51	20.94	-0.2357	0.1440	13.46	14.74	16.17	17.7842	19.60	21.65	23.96		
17.50 – 17.99	0.5569	0.1137	13.41	14.60	15.83	17.1023	18.42	19.78	21.18	-0.2467	0.1445	13.58	14.87	16.32	17.9474	19.79	21.86	24.22		
18.00 – 18.49	0.6138	0.1111	13.70	14.90	16.13	17.3979	18.70	20.05	21.43	-0.2577	0.1450	13.66	14.96	16.42	18.0690	19.93	22.03	24.42		

The LMSChartmaker was used to calculate all estimates, L denotes box power to remove skewness, M denotes the median and S, the coefficient of variation. The LMS parameters can be used to calculate the z score of completed BMI of a child or adolescent with the help of the formula: $[(BMI \div MJL) - 1] \div S \times L$ that approximates to the nearest completed 6-months of age

parts of the world, Africa remains a continent where children and adolescents suffer from nutritional inadequacies [21, 31]. The rates of severe (z-score <-3) and moderate (z-score <-2) stunting in the overall population were 4.4% and 14.3%, respectively. The rates of severe and moderate stunting in boys (5.6% and 17.8%) and girls (3.2% and 10.9%) showed significant sexual dimorphism. The growth patterns in height of Nigerian children and adolescents are better than those reported in some African countries. The rates in Tanzania were 30% [32], and in rural Mozambique, stunting rates of 24.2% for boys and 21.1% for girls have been reported [33]. A lower prevalence of stunting has been reported in other studies, 8.8% in Burkina Faso [30] and 7.2% in Addis Ababa [35]. The rate of stunting seen in this study is of great concern to children and adolescents, especially girls, whose stature has the potential to transcend one generation and its consequences for parturition. Even though nutritional interventions during the first 1000 days are the most important way to prevent short stature, there is evidence that interventions during adolescence offer another chance to break the cycle of undernutrition that can last for generations [36].

Agriculture is the mainstay of the Nasarawa economy, with maize, rice and yam being the most popular foods. Looking at the types of foods that a subset of the population has access to shows that most of the people in this study have access to carbohydrate-rich foods. This may help explain the high level of chronic undernutrition seen in this paper. These food types predominantly provide the body with its energy needs and are often prepared and served with little or no protein (for bodybuilding and repair of muscles and bones), such as meat, fish, eggs, or beans. Furthermore, intakes of certain vitamins are variable and may have been affected by seasonality and access to homegrown fruits and vegetables. As a result, their bodies' overall energy intake was not restricted, but their protein, micronutrient, and macronutrient intakes remained concerning. Other researchers have discovered a correlation between not getting enough nutrients and being short for age [37, 38]. Thinness was the most prevalent burden of undernutrition observed in this study. The prevalence of severe (z-score <-3) and moderate (z-score <-2) thinness in the combined population was 23.0% and 47.8%, respectively. The rates of severe and moderate thinness were 27.5%

and 52.4% in boys. In girls, the rates of severe and moderate thinness were 18.8% and 43.7%, respectively. This level of thinness in an urban setting is a serious public health concern, considering its association with starvation. Despite differences in methodologies and/or criteria used for the assessment of nutritional status, evidence from studies in other parts of Africa has shown high rates of thinness [38–40]. The high prevalence of thinness seen in this study is an indication of the remarkable condition of chronic protein energy deficiency among Nigerian children and adolescents. Socioeconomic factors such as family income, family size, and parental educational status may influence nutritional status. Children from families with a high socioeconomic status and higher parental education are more likely to have access to better nutrition than their peers from families with a lower socioeconomic status. The findings in this study further support the view that insecurity, inflation, and ethno-religious crises might have heightened food insecurity in Nigeria. Evidence from the educational attainments and occupations of study participants' parents (data not included) revealed that poverty and ignorance may have influenced the level of undernutrition seen in this study, as most parents reported having no formal education or having only primary education. The most commonly reported means of livelihood of parents are trading and farming.

Our findings that girls have better nutritional status than boys are consistent with prior research in Sub-Saharan Africa [33, 41–44]. In the subjects in this study, the mean z-scores of height-for-age for all subjects, boys and girls, were -0.68 ± 1.37 , -0.80 ± 1.47 , and -0.57 ± 1.26 , respectively. The mean z-scores of BMI-for-age for the overall subjects, boys and girls, were respectively -1.94 ± 1.32 , -2.16 ± 1.31 , and -1.75 ± 1.31 . The negative z-scores for anthropometric data are consistent with findings in other parts of Africa. The z-scores for boys were significantly lower compared to girls, which suggests that boys are more susceptible to undernutrition than girls. Although it is hard to overstate the fact that obesity has remained a major public health concern worldwide, while developing countries suffer from double burden malnutrition (coexistence of under and overnutrition), that doesn't seem to be the case with the subjects in this study. Evidence suggests that this disparity between boys and girls may be due to the greater adaptation of girls to harmful environmental

conditions than boys [45, 46], boys' engagement in strenuous physical activities after school than girls, and gender bias in terms of increased attention on female children has resulted in better nutrition in girls than in boys. The sex difference in the pattern of growth may be due to intensive exercise (high energy expenditure) among boys rather than girls. For instance, it is common practice for boys of the age considered in this study to engage in hawking, skill acquisition, or support their parents on farms (especially during the rainy season) after school. Furthermore, differences in pubertal timing between boys and girls have also been reported as factors influencing growth and nutritional status [45].

We present smoothed reference percentile curves for the height, weight and BMI of children and adolescents aged 5–18 years. There was no subnational or national prevalence of stunting and thinness in children and adolescents aged 5–18 years for comparison with the present study. However, the nutritional status of Nigerian children and adolescents as assessed from height-for-age and BMI-for-age reference curves indicates that most of them are undernourished based on the WHO (2007) definitions (Figure 1). The 3rd and 50th growth curves of height-for-age in Nigerian children and adolescents of both sexes remain below the corresponding percentiles of WHO (2007) references. This is in concordance with previous findings in other sub-Saharan African countries [32, 41]. Although the growth curves of height-for-age of Nigerian children and adolescents remain below the 3rd and 50th percentiles of the WHO (2007) reference data, the 97th percentiles for Nigerian children were just above the WHO (2007) reference data from age 5–14 years, after which the trend reversed with WHO (2007) being above their Nigerian peers. It is observed that the linear growth of Nigerian children accelerates between the ages of 5–14 years in both sexes, then begins to falter. The gradual decline in height might indicate a decline in pubertal growth spurt. The decelerating growth pattern at adolescence observed in this study is similar to that earlier reported in the Nigerian population [47]. Using the LMS parameters that are sex- and age-specific to the nearest six months, z-scores can be calculated that match the new reference percentiles for a given traditional anthropometric measurement (x) such as height, weight, or BMI. This can be done with the following equation:

$$z\text{-score} = [(x \div M) - 1] \div S \times L$$

In conclusion, to our knowledge, no study has been conducted in Lafia, Nasarawa State, to assess the nutritional status and generate new reference percentile ranges for height, weight, and BMI and LMS coefficients needed for the estimation of the z-score based on age and sex. The present study reveals a high prevalence of undernutrition among children and adolescents in Lafia metropolis. The prevalence of thinness and stunting was higher in boys compared to girls. This study also showed that the height and BMI percentile curves of children and adolescents in Nigeria are below WHO (2007) reference data.

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