

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

Background: Nutritional status and growth patterns are key indicators of a population's socioeconomic wellbeing, 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. The aim of this study was to find out how common undernutrition is and to generate reference percentile ranges for height, weight and BMI.

Methods: 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 into nutritional status was made according to 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 moderate and severely thinned boys were 52.4% and 27.5%. In girls, the incidence of moderate and severe stunting was 10.9 % and 3.2 %, respectively, whereas the prevalence of moderate and severe thinness was 43.7 % and 18.8

Conclusions: 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 with 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.

Background

Anthropometric parameters are important for growth monitoring and are indicators of 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 as regards the adoption of international cut-off points for anthropometric measures to detect growth pattern and nutritional status. The disagreements over the cut-offs stem from its importance, applicability and biological definition of cut-off points for different populations resident in different geographic locations [1–3]. That notwithstanding, anthropometric measurements are still considered the most effective and useful method to screen physical growth and nutritional needs assessment in nutritional anthropometry, given that they provide additional insights on essential aspects of human growth, nutrition and adaptation to adverse environmental conditions [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 have provided support for the hypothesis that those with bigger body size are at advantage. There has been renewed debate on whether interventions at adolescent could compensate both linear growth deficits [5, 6] and cognitive achievements [7–9] earlier in life. Adolescence – usually defined as 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, presents an opportunity for accelerated growth [6, 11] and increased maternal height is expected to lead to improved outcomes in children⁸. Furthermore, women who were born stunted and remained stunted at 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 deficit as adults were approximately 15% more likely to experience height deficit at childhood and are 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 standard deviation 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 is 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 at infancy, can occur at childhood and adolescence [7, 8, 14]. For example, large surveys in low-and middle-income countries, show that children who were height deficit at childhood recovered from stuntedness at adolescence. Although there is evidence that nutritional interventions beyond infancy led to nutritional improvement, however, this impact is rather smaller compared to interventions made at infancy [15]. Evidence linking improved nutrition beyond the first 1000 days and cognitive achievements have produced variable results [7,9,13,15]. 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 in life and cognitive achievement may deserve attention.

Nevertheless, with regard to children and adolescents aged 5–18 years old in Nigeria, their growth pattern and nutritional status remains unknown. Growth and nutritional status in these population have not been evaluated probably because it has not been seen as a priority issue by health authorities or due to its cost implication to generate using traditional extemporaneous cross-sectional study. Moreover, presently available information on growth and nutritional status of children and adolescent in Nigeria is inconsistent and remains unclear. However, evidence demonstrating undernutrition in children and adolescents as a major public health problem in Nigeria is mounting [16, 17].

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

Methods

Participants

Subjects from the study are children and adolescents from Lafia the capital city of Nasarawa State, Northcentral Nigeria. The region is served with relatively stable electricity supply. However, households provide water for themselves through 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. Modern Lafia is an administrative and 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 prior to 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 comprised 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 Ahmadu Bello University Ethics Committee on the Use of Human Subjects in Research gave its approval to the study. 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 caregiver 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 Statistical Product and Service Solutions (SPSS) date and time wizard expressed in months.

Anthropometric Measurements

Height was measured in cm with a portable stadiometer with the subject standing straight, with 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, bare-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 [18]. 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” [19], 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, 20]. 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 heights 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 [21] 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 (2007). 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 [22].

Results

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

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

| | | Boys (n = 1,541) | | | Girls (n = 1,650) | | |
|--------|-----|------------------|---------------|--------------------------|-------------------|--------------|--------------------------|
| | | Height (cm) | Weight (kg) | BMI (kgm ⁻²) | Height (cm) | Weight (kg) | BMI (kgm ⁻²) |
| Age, y | n | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | Mean ± SD | 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 |

The prevalence of severe stunting (height-for-age <-3 SD), moderate stunting (height-for-age <-3 SD) and normal stature (height-for-age > +1 SD) for each 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). With the exception of 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 age 15 years for boys and 14 years for girls. The severity and moderate stunting ranges in boys (0.0–20.6% and 2.5–46.8%) and girls (0.0–9.9% and 0.0–19.8%), respectively. Sex-wise comparison of moderate and severe stunting revealed that boys are two times more likely to be stunted than girls. In both sexes, stunting was higher among adolescents than non-adolescents and tends to decrease in late adolescence.

Table 2
z-scores for HAZ by age and sex mean \pm SD (95% CI) and prevalence of normal height and stunting by age and sex

| Z-scores for HAZ by age and sex (mean \pm SD (95% CI) and prevalence of normal height and stunting by age and sex) | | | | | | | | | | | | | | | |
|--|------------------|----------------|------|------|------|------------------|----------------|------|------|------|------------------|----------------|------|------|------|
| Combined population | | | | | | Boys | | | | | Girls | | | | |
| | HAZ | | SS | MS | NH | HAZ | | SS | MS | NH | HAZ | | SS | MS | NH |
| Age, y | Mean \pm SD | 95% CI | < -3 | < -2 | > +1 | Mean \pm SD | 95% CI | < -3 | < -2 | > +1 | Mean \pm SD | 95% CI | < -3 | < -2 | >+1 |
| 5 | 0.61 \pm 1.66 | (0.23, 1.00) | 1.4 | 1.4 | 35.7 | 0.88 \pm 1.98 | (0.27, 1.49) | 2.5 | 2.5 | 47.5 | 0.26 \pm 1.01 | (-0.10, 0.62) | 0.0 | 0.0 | 20.0 |
| 6 | -0.06 \pm 1.38 | (-0.23, 0.11) | 0.0 | 6.5 | 19.6 | -0.03 \pm 1.44 | (-0.29, 0.22) | 0.0 | 6.5 | 24.4 | -0.09 \pm 1.32 | (-0.31, 0.13) | 0.0 | 6.6 | 15.3 |
| 7 | -0.33 \pm 1.58 | (-0.63, -0.02) | 2.9 | 7.8 | 21.4 | -0.53 \pm 1.45 | (-0.95, -0.12) | 2.1 | 8.5 | 17.0 | -0.16 \pm 1.67 | (-0.59, 0.28) | 3.6 | 7.1 | 25.0 |
| 8 | -0.34 \pm 1.13 | (-0.50, -0.19) | 0.0 | 6.2 | 10.4 | -0.38 \pm 1.09 | (-0.57, -0.20) | 0.0 | 6.6 | 8.8 | -0.27 \pm 1.22 | (-0.55, 0.00) | 0.0 | 5.3 | 13.3 |
| 9 | -0.42 \pm 1.25 | (-0.57, -0.27) | 0.8 | 8.3 | 12.9 | -0.28 \pm 1.33 | (-0.49, -0.07) | 0.6 | 7.1 | 14.9 | -0.63 \pm 1.10 | (-0.84, -0.43) | 0.9 | 10.0 | 10.0 |
| 10 | -0.57 \pm 1.34 | (-0.73, -0.40) | 1.2 | 9.8 | 11.8 | -0.56 \pm 1.43 | (-0.82, -0.31) | 1.7 | 9.2 | 14.2 | -0.57 \pm 1.27 | (-0.79, -0.31) | 0.8 | 10.3 | 9.5 |
| 11 | -0.82 \pm 1.21 | (-0.97, -0.68) | 4.2 | 12.7 | 7.8 | -0.80 \pm 1.19 | (-1.00, -0.61) | 4.3 | 11.4 | 7.1 | -0.85 \pm 1.22 | (-1.05, -0.65) | 4.2 | 14.0 | 8.4 |
| 12 | -0.89 \pm 1.41 | (-1.08, -0.71) | 6.8 | 15.1 | 6.8 | -0.80 \pm 1.35 | (-1.04, -0.55) | 4.2 | 11.0 | 7.6 | -1.00 \pm 1.46 | (-1.29, -0.72) | 9.9 | 19.8 | 5.9 |
| 13 | -0.76 \pm 1.47 | (-0.93, -0.59) | 4.1 | 18.0 | 11.9 | -0.67 \pm 1.63 | (-0.95, -0.39) | 2.4 | 18.9 | 16.5 | -0.83 \pm 1.35 | (-1.03, -0.63) | 5.4 | 17.3 | 8.3 |
| 14 | -1.22 \pm 1.35 | (-1.37, -1.06) | 9.9 | 29.0 | 6.1 | -1.56 \pm 1.37 | (-1.79, -1.32) | 14.0 | 41.1 | 7.8 | -0.95 \pm 1.28 | (-1.14, -0.75) | 6.7 | 19.5 | 4.9 |
| 15 | -1.23 \pm 1.35 | (-1.37, -1.08) | 11.1 | 27.7 | 3.7 | -1.93 \pm 1.22 | (-2.13, -1.73) | 20.6 | 46.8 | 0.0 | -0.68 \pm 1.18 | (-0.85, -0.51) | 3.8 | 13.0 | 6.5 |
| 16 | -0.77 \pm 1.14 | (-0.91, -0.63) | 4.2 | 15.2 | 3.8 | -1.40 \pm 1.23 | (-1.63, -1.16) | 9.7 | 35.0 | 2.9 | -0.36 \pm 0.86 | (-0.50, -0.23) | 0.6 | 2.5 | 4.4 |
| 17 | -0.62 \pm 1.16 | (-0.78, -0.47) | 3.9 | 9.2 | 3.9 | -1.20 \pm 1.24 | (-1.46, -0.93) | 8.4 | 18.1 | 2.4 | -0.24 \pm 0.91 | (-0.40, -0.07) | 0.8 | 3.3 | 4.9 |
| 18 | -0.75 \pm 1.20 | (-0.94, -0.56) | 5.2 | 9.2 | 6.5 | -0.95 \pm 1.13 | (-1.20, -0.70) | 5.0 | 10.0 | 5.0 | -0.53 \pm 1.24 | (-0.81, -0.24) | 5.5 | 8.2 | 8.2 |
| Total | -0.68 \pm 1.37 | (-0.73, -0.64) | 4.4 | 14.3 | 9.8 | -0.80 \pm 1.47 | (-0.88, -0.73) | 5.6 | 17.8 | 10.9 | -0.57 \pm 1.26 | (-0.63, -0.51) | 3.2 | 10.9 | 8.8 |
| HAZ, height-for-age z-score; SS, severely stunted; MS, moderately stunted; NH, normal height | | | | | | | | | | | | | | | |

Table 3 provides the prevalence of thinness per age group for the overall population and separated by sex. The prevalence of moderate and severe thinness for 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 that 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 analyses.

Table 3
z-scores for BMI-for-age by age and sex mean \pm SD (95% CI) and prevalence of thinness and stunting by age and sex

| Combined population | | | Boys | | | | Girls | | | | | |
|--|---------------------|-------------------|----------|----------|---------------------|-------------------|----------|----------|---------------------|-------------------|----------|----------|
| Age, y | BAZ | | ST | MT | BAZ | | ST | MT | BAZ | | ST | MT |
| | Mean \pm SD | 95% CI | < — 3 | < — 2 | Mean \pm SD | 95% CI | < — 3 | < — 2 | Mean \pm SD | 95% CI | < — 3 | < — 2 |
| 5 | −1.60 \pm 1.54 | (−1.96, −1.23) | 20.3 | 34.8 | −1.63 \pm 1.72 | (−2.17, −1.09) | 20.5 | 33.3 | −1.55 \pm 1.28 | (−2.01, −1.09) | 20.0 | 36.7 |
| 6 | −1.51 \pm 1.43 | (−1.69, −1.34) | 14.9 | 35.1 | −1.80 \pm 1.21 | (−2.01, −1.58) | 17.9 | 43.1 | −1.27 \pm 1.57 | (−1.53, −1.01) | 12.2 | 28.1 |
| 7 | −1.73 \pm 1.36 | (−2.00, −1.47) | 20.4 | 40.8 | −1.83 \pm 1.38 | (−2.22, −1.43) | 21.3 | 42.6 | −1.65 \pm 1.34 | (−2.00, −1.30) | 19.6 | 39.3 |
| 8 | −2.02 \pm 1.24 | (−2.19, −1.85) | 21.6 | 48.1 | −2.10 \pm 1.29 | (−2.31, −1.88) | 26.7 | 48.9 | −1.88 \pm 1.14 | (−2.15, −1.62) | 12.3 | 46.6 |
| 9 | −2.38 \pm 1.32 | (−2.55, −2.22) | 33.3 | 59.9 | −2.68 \pm 1.31 | (−2.89, −2.46) | 40.6 | 64.3 | −2.00 \pm 1.25 | (−2.24, −1.76) | 23.9 | 54.1 |
| 10 | −2.34 \pm 1.17 | (−2.49, −2.19) | 29.2 | 65.7 | −2.10 \pm 1.23 | (−2.33, −1.88) | 24.1 | 58.9 | −2.56 \pm 1.08 | (−2.75, −2.37) | 33.9 | 71.8 |
| 11 | −2.20 \pm 1.26 | (−2.35, −2.05) | 30.0 | 57.8 | −2.26 \pm 1.34 | (−2.48, −2.03) | 35.0 | 55.5 | −2.15 \pm 1.18 | (−2.34, −1.95) | 25.0 | 60.0 |
| 12 | −2.22 \pm 1.24 | (−1.71, −2.05) | 25.4 | 56.9 | −2.45 \pm 1.34 | (−2.70, −2.20) | 34.5 | 59.1 | −1.97 \pm 1.07 | (−2.18, −1.76) | 15.2 | 54.5 |
| 13 | −1.55 \pm 1.42 | (−2.20, −1.38) | 17.4 | 40.3 | −1.66 \pm 1.48 | (−1.93, −1.40) | 19.8 | 43.8 | −1.46 \pm 1.38 | (−1.67, −1.25) | 15.6 | 37.7 |
| 14 | −2.11 \pm 1.34 | (−2.26, −1.96) | 29.7 | 54.5 | −2.33 \pm 1.25 | (−2.55, −2.12) | 33.9 | 56.7 | −1.94 \pm 1.39 | (−2.15, −1.72) | 26.4 | 52.8 |
| 15 | −2.06 \pm 1.24 | (−2.20, −1.93) | 24.8 | 50.9 | −2.44 \pm 1.22 | (−2.64, −2.23) | 34.8 | 62.3 | −1.78 \pm 1.19 | (−1.95, −1.61) | 17.4 | 42.4 |
| 16 | −1.79 \pm 1.29 | (−1.94, −1.63) | 20.5 | 39.5 | −2.13 \pm 1.24 | (−2.37, −1.89) | 23.8 | 49.5 | −1.56 \pm 1.27 | (−1.76, −1.36) | 18.4 | 32.9 |
| 17 | −1.62 \pm 1.18 | (−1.78, −1.46) | 13.1 | 34.5 | −2.16 \pm 1.03 | (−2.39, −1.94) | 18.1 | 50.6 | −1.25 \pm 1.14 | (−1.45, −1.05) | 9.8 | 23.6 |
| 18 | −1.58 \pm 1.05 | (−1.75, −1.42) | 9.9 | 29.1 | −1.84 \pm 0.86 | (−2.03, −1.65) | 12.8 | 37.2 | −1.31 \pm 1.17 | (−1.58, −1.04) | 6.8 | 20.5 |
| Total | −1.94 \pm 1.32 | (−1.99, −1.90) | 23.0 | 47.8 | −2.16 \pm 1.31 | (−2.22, −2.09) | 27.5 | 52.4 | −1.75 \pm 1.31 | (−1.81, −1.69) | 18.8 | 43.7 |
| BAZ, BMI-for-age z-score; ST, severe thinness; MT, moderate thinness | | | | | | | | | | | | |

Tables 4–6 documents the smoothed percentile distributions (3rd, 10th, 25th, 50th, 75th, 90th and 97th). Graphical comparisons of the new growth charts for height and BMI to the WHO (2007) by using the third, 50th and 97th percentiles are depicted by age and sex in Fig. 1. Estimates are calculated at 6-month intervals from 5 to 18 years.

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

| Boy | | | | | | | | | | | | | | | |
|-------------|---|--------|--------|--------|--------|----------|--------|--------|--------|---|--------|--------|--------|--------|-------|
| Age, y | L | S | 3rd | 10th | 25th | M | 75th | 90th | 97th | L | S | 3rd | 10th | 25th | M |
| 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 | 110.3 |
| 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 | 112.7 |
| 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 | 115.1 |
| 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 | 117.4 |
| 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 | 119.8 |
| 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 | 122.2 |
| 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 | 124.5 |
| 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 | 126.9 |
| 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 | 129.3 |
| 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 | 131.6 |
| 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 | 134.0 |
| 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 | 136.4 |
| 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 | 138.7 |
| 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 | 141.0 |
| 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 | 143.2 |
| 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 | 145.4 |
| 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 | 147.5 |
| 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 | 149.5 |
| 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 | 151.4 |
| 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 | 153.2 |
| 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 | 154.9 |
| 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 | 156.5 |
| 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 | 158.1 |
| 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 | 159.6 |
| 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 | 161.0 |

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. to calculate the z score of completed height of a child or adolescent with the help of the formula: $[(\text{height} \div M)^L - 1] \div S \times L$ that approximate to the nearest

| Boy | | | | | | | | | | | | | | | |
|--|---|--------|--------|--------|--------|----------|--------|--------|--------|---|--------|--------|--------|--------|-------|
| 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 | 162.5 |
| 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 | 163.9 |
| 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. to calculate the z score of completed height of a child or adolescent with the help of the formula: [(height ÷ M) ^L – 1] ÷ S × L that approximate to the nearest | | | | | | | | | | | | | | | |

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 (Figs. 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 comparison of the 3rd and 50th percentiles of the new growth chart for height was symmetrical to the WHO (2007) chart, with the 3rd percentile of Nigerian girls 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, 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 modelling 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.

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

| Boy | | | | | | | | | | | | | | | |
|-------------|---------|--------|-------|-------|-------|---------|-------|-------|-------|---------|--------|-------|-------|-------|-------|
| Age, y | L | S | 3rd | 10th | 25th | M | 75th | 90th | 97th | L | S | 3rd | 10th | 25th | M |
| 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 | 15.86 |
| 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 | 16.73 |
| 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 | 17.54 |
| 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 | 18.25 |
| 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 | 18.85 |
| 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 | 19.37 |
| 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 | 19.88 |
| 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 | 20.46 |
| 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 | 21.22 |
| 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 | 22.23 |
| 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 | 23.49 |
| 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 | 24.98 |
| 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 | 26.72 |
| 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 | 28.73 |
| 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 | 30.87 |
| 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 | 32.99 |
| 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 | 34.96 |
| 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 | 36.71 |
| 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 | 38.24 |
| 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 | 39.64 |
| 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 | 41.04 |
| 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 | 42.54 |
| 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 | 43.99 |
| 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 | 45.20 |
| 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 | 46.08 |

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. used to calculate the z score of completed weight of a child or adolescent with the help of the formula: $[(\text{weight} \div M)^L - 1] \div S \times L$ that approximate to the of age

| Boy | | | | | | | | | | | | | | | |
|---|--------|--------|-------|-------|-------|---------|-------|-------|-------|--------|--------|-------|-------|-------|-------|
| 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 | 46.62 |
| 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 | 46.97 |
| 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. used to calculate the z score of completed weight of a child or adolescent with the help of the formula: $[(\text{weight} \div M)^L - 1] \div S \times L$ that approximate to the of age | | | | | | | | | | | | | | | |

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 for 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) (Figs. 1c and 1d). The median BMI for Nigerian boys and girls approximates the 3rd percentile across all ages. The 97th percentiles of Nigerian children track neatly along with the median of the WHO (2007) across several ages, especially in girls (Fig. 1d).

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

| Boy | | | | | | | | | | | | | | | |
|-------------|---------|--------|-------|-------|-------|---------|-------|-------|-------|---------|--------|-------|-------|-------|-------|
| Age, y | L | S | 3rd | 10th | 25th | M | 75th | 90th | 97th | L | S | 3rd | 10th | 25th | M |
| 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 | 13.26 |
| 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 | 13.24 |
| 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 | 13.19 |
| 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 | 13.12 |
| 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 | 13.03 |
| 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 | 12.94 |
| 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 | 12.88 |
| 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 | 12.88 |
| 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 | 12.91 |
| 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 | 12.98 |
| 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 | 13.13 |
| 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 | 13.39 |
| 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 | 13.75 |
| 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 | 14.16 |
| 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 | 14.60 |
| 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 | 15.03 |
| 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 | 15.41 |
| 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 | 15.74 |
| 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 | 16.02 |
| 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 | 16.30 |
| 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 | 16.60 |
| 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 | 16.92 |
| 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 | 17.25 |
| 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 | 17.54 |
| 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 | 17.78 |

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. used to calculate the z score of completed BMI of a child or adolescent with the help of the formula: $[(\text{BMI} \div \text{M})^L - 1] \div S \times L$ that approximate to the nearest age

| Boy | | | | | | | | | | | | | | | |
|---|--------|--------|-------|-------|-------|---------|-------|-------|-------|---------|--------|-------|-------|-------|-------|
| 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 | 17.94 |
| 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 | 18.06 |
| 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. used to calculate the z score of completed BMI of a child or adolescent with the help of the formula: $[(BMI \div M)^L - 1] \div S \times L$ that approximate to the nearest age | | | | | | | | | | | | | | | |

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 programme. Third, the functional performance of adults is significantly associated with their extent of stunting at childhood [23], and women who were stunted earlier in life and remained stunted as adults, are more likely to have stunted children¹². 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 [24]. A narrow pelvis can lead to protracted labour and often damages the newborn.

Despite the fact that undernutrition has decreased in many parts of the world, Africa remains a continent where children and adolescents suffer from nutritional inadequacies [16, 25]. 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% [26], in rural Mozambique, stunting rates of 24.2% for boys and 21.1% for girls have been reported [27]. A lower prevalence of stunting has been reported in other studies, 8.8% in Burkina Faso [28] and 7.2% in Addis Ababa [29]. 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.

Agriculture is the mainstay of the Nasarawa economy, with maize, rice and yam being the most popular foods. An examination of patterns of foods available to a subsample of the population suggests that the majority of the subjects have access to carbohydrate rich foods, which may probably justify the level of chronic undernutrition observed 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 body building 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 [30, 31].

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%. 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 assessment of nutritional status, evidence from studies in other parts of Africa has shown high rates of thinness [31–33]. 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 a subset of the subjects revealed that poverty and ignorance may have influenced the level of undernutrition seen in this study.

Our findings that girls have better nutritional status than boys are consistent with prior research in Sub-Saharan Africa [27, 34–37]. 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 greater adaptation of girls to harmful environmental conditions than boys [38, 39], 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 [38].

We present smoothed reference percentile curves for height, weight and BMI of children and adolescents aged 5–18 years. There was no subnational or national prevalence of stunting and thinness of 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 undernutrition prevailed in these children and adolescents compared to the WHO (2007) definitions (Fig. 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 [26, 34]. 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 [40]. With the help of the LMS parameters that are sex- and age-specific to the nearest completed 6-months of age for a child or adolescent, z-scores can be calculated that match the new reference percentiles for a given traditional anthropometric measurement (x) (i.e., height, weight, or BMI) with the equation:

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

In conclusion, to our knowledge, no study has been conducted in Lafia, Nasarawa State with a view to assessing the nutritional status and generating new reference percentile ranges for height, weight and BMI and LMS coefficients needed for estimation of 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.

Declarations

Ethics approval and consent to participate

The study complies with the Declaration of Helsinki and ethical approval was obtained from Ahmadu Bello University Ethics Committee on Use of Human Subjects for Research with approval number (ABUCUHSR/2018/004). The purpose, contents of the questionnaire and the study procedures were fully explained to school authorities. Only schools whose authorities gave their approval to participate in the study were sampled. Children less than 18 years old were unable to give permission to participate in the study. Therefore, parental permission was requested for each child less than 18 years old using informed written consent while participants 18 years old have to sign an informed consent to participate. Only children whose parents willingly gave their informed consent participated in the study. The children also gave their informed consent to affirming their willingness to participate in the study.

Consent to publish

Not applicable.

Availability of data and materials

There are no linked research datasets for this study to maintain confidentiality of participant responses. Data will be made available by the corresponding author on reasonable request.

Competing interests

The authors declare that they have no competing interests.

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Authors Contribution

NM conceived and designed the study and involved in data acquisition, analysis, interpretation and drafting of the manuscript. DB, MSA and AAS participated in interpretation of the data, drafting and reviewing the manuscript. All authors read and approved the final manuscript.

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Figures

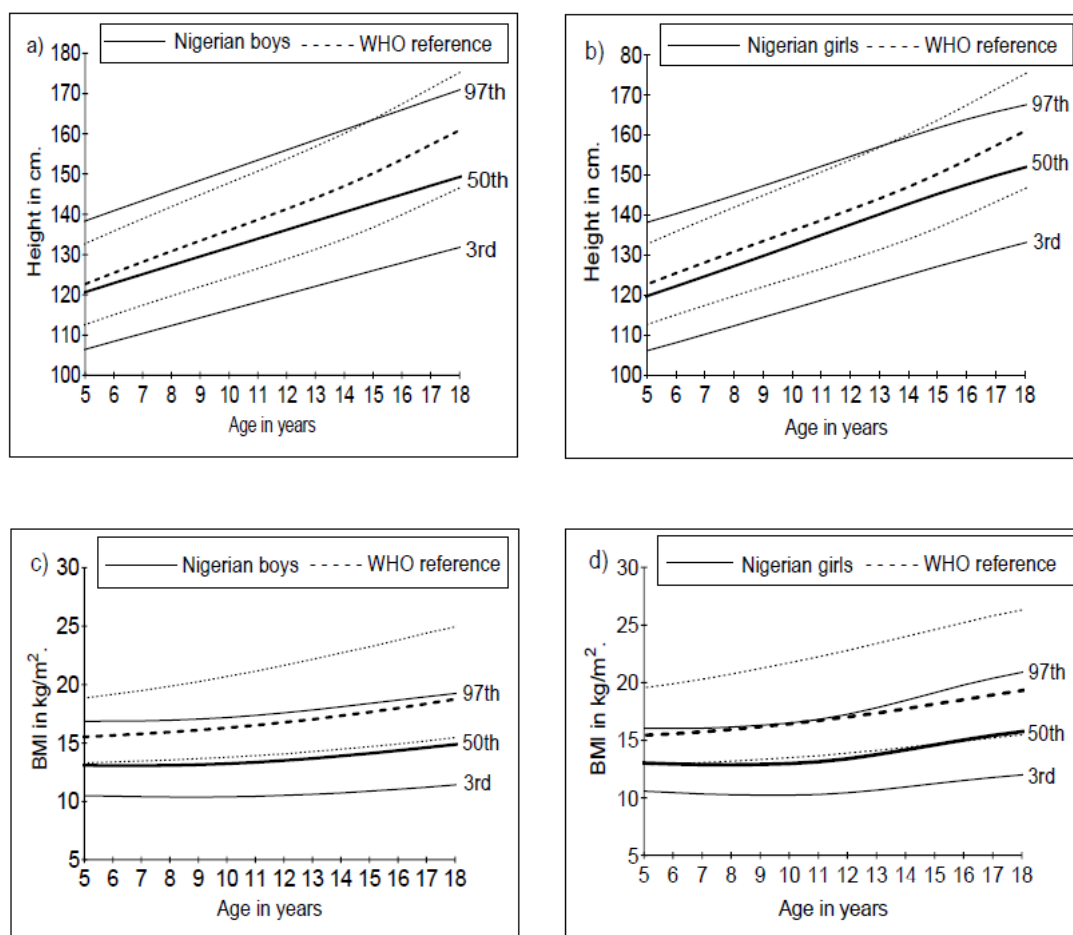


Figure 1
Height-for-age (a, b) and BMI-for-age (c, d) percentiles of boys and girls from Nigeria (solid lines) compared to WHO (2007) reference data (dashed lines).