Applied Sciences, Computing and Energy, 2024, 1(1), 387-402

Symmetry of Age and Sex Distributions in a Cross-sectional Nutrition Survey of Children Under Five in Bolori II, Monguno, and Pulka, Nigeria (2022–2023)

Anthony Ekpo* and Ikughur, Jonathan Atsue

Received: 19 August 2024/Accepted: 12 December 2024/Published: 31 December 2024

Abstract: *Reliable nutrition surveys require representative age and sex distributions to ensure accurate estimation of malnutrition prevalence. This study evaluated the symmetry of age and sex distributions among children aged 6–59 months using data from cross-sectional SMART nutrition surveys conducted in Bolori II, Monguno, and Pulka, Borno State, Nigeria, during 2022–2023. A two-stage cluster sampling technique based on Probability Proportional to Size (PPS) was employed, yielding samples of 785, 592, and 574 children from Bolori II, Monguno, and Pulka, respectively. Age and sex distributions were assessed using frequency distributions, sex ratios, chi-square tests, and anthropometric quality indicators, while Weight-for-Height (WHZ) distributions were compared with the WHO reference standard. The overall male-to-female sex ratios were 1.02, 0.87, and 1.03 for Bolori II, Monguno, and Pulka, respectively, with no statistically significant differences in sex distribution (p = 0.803, 0.100, and 0.738). Mean WHZ values were −0.76 ± 1.05, −1.20 ± 1.18, and −0.57 ± 1.19, indicating poorer nutritional status than the WHO reference, particularly in Monguno. The WHZ distributions exhibited approximately symmetrical bell-shaped patterns with substantial overlap between boys and girls, while design effects ranged from 1.00 to 2.60, confirming acceptable survey quality. Overall, the findings demonstrate that the SMART methodology produced representative and statistically reliable datasets suitable for estimating malnutrition prevalence and supporting evidence-based nutrition interventions in conflict-affected communities.*

Keywords: *Symmetry, age distribution, sex ratio, SMART survey, anthropometric assessment*

Anthony Ekpo
Department of Statistics, Federal University of Agriculture, Makurdi, Benue State, Nigeria.
Email: ekpo.anthony@uam.edu.ng
https://orcid.org/0000-0002-1896-6458

Jonathan Atsue Ikughur
Department of Statistics, Federal University of Agriculture, Makurdi, Benue State, Nigeria.
Email: ikughur.jonathan@uam.edu.ng
https://orcid.org/0000-0003-1276-668X

1.0 Introduction

Child malnutrition remains one of the leading public health challenges worldwide and is a major contributor to childhood morbidity, mortality, impaired cognitive development, and poor socioeconomic outcomes. Despite global efforts to improve child nutrition through the Sustainable Development Goals (SDGs) and the World Health Organization (WHO) Global Nutrition Targets 2025, millions of children under five years of age continue to experience undernutrition in the form of stunting, wasting, and underweight, particularly in low- and middle-income countries affected by poverty, food insecurity, and humanitarian crises (Gupta et al., 2019). In Nigeria, the burden of malnutrition is further aggravated by armed conflict, population displacement, limited access to healthcare, and disruptions in food systems, especially in the northeastern region where recurrent humanitarian emergencies have significantly affected the nutritional status of children.

Reliable assessment of nutritional status is fundamental for planning, implementing, and evaluating nutrition interventions. Anthropometric measurements, including weight-for-height, height-for-age, weight-for-age, and mid-upper arm circumference (MUAC), remain the internationally accepted indicators for identifying acute and chronic malnutrition among children under five years of age. These measurements are routinely collected through standardized cross-sectional nutrition surveys conducted according to the Standardized Monitoring and Assessment of Relief and Transitions (SMART) methodology. The SMART approach provides standardized procedures for sampling, data collection, quality assurance, and statistical analysis, thereby ensuring that nutrition surveys produce representative and reliable estimates for humanitarian decision-making (Grellety & Golden, 2018).

Cross-sectional nutrition surveys are widely used because they provide rapid estimates of the prevalence of malnutrition and associated health indicators within a defined population at a particular point in time. Their relatively low cost, operational simplicity, and suitability for emergency settings make them indispensable tools for nutritional surveillance and programme evaluation. However, the validity of prevalence estimates depends largely on the representativeness and quality of the sampled population. Sampling bias, inaccurate age determination, unequal representation of sexes, and data-entry errors can compromise survey findings and consequently affect intervention planning (Wang & Cheng, 2020). Therefore, routine assessment of survey quality has become an essential component of SMART nutrition surveys.

One important aspect of survey quality assessment involves evaluating the statistical distribution of demographic variables, particularly age and sex. Age and sex constitute the principal stratification variables in nutrition surveys because anthropometric indicators are strongly influenced by these demographic characteristics. Ideally, the distributions of sampled children should closely resemble the expected population structure, without excessive asymmetry or abnormal concentration within particular age or sex categories. Statistical measures such as skewness and kurtosis provide objective methods for assessing the symmetry and shape of these distributions. Skewness measures the degree of asymmetry of a distribution around its mean, whereas kurtosis evaluates the degree of peakedness or flatness relative to a normal distribution. Values close to zero indicate distributions that approximate normality and generally reflect good sampling quality.

Recognizing the importance of data quality, WHO and SMART introduced standardized quality-control procedures, including automated flagging algorithms for identifying biologically implausible anthropometric measurements. Since the implementation of these standardized procedures, the distributions of anthropometric indices have become increasingly consistent with WHO Child Growth Standards, while survey quality has improved considerably when appropriate outlier detection procedures are applied (Grellety & Golden, 2018). Nevertheless, demographic characteristics such as age and sex distributions remain important complementary indicators for evaluating sampling quality because even accurate anthropometric measurements may yield biased prevalence estimates if the sampled population is not demographically representative.

Several studies have demonstrated the importance of anthropometric assessment in understanding childhood nutritional status across different populations. Gupta et al. (2019) reported that approximately 54.4% of children aged 1–5 years in rural Haryana, India, were undernourished when assessed using the Composite Index of Anthropometric Failure (CIAF), highlighting the value of comprehensive anthropometric assessment for nutrition policy formulation. Similarly, Akhlaghi et al. (2013) observed high frequencies of wasting, underweight, and stunting among infants in Yasuj, Iran, and identified parental education, maternal age, and birth interval as important determinants of childhood malnutrition. In Nigeria, Ene-Obong et al. (2012) reported considerable levels of overweight, obesity, and thinness among school-aged children and adolescents, demonstrating that nutritional problems may vary across age groups and sexes. These findings collectively underscore the importance of obtaining representative demographic samples to ensure accurate estimation of nutritional indicators.

In humanitarian settings such as northeastern Nigeria, SMART nutrition surveys have become the principal mechanism for monitoring child nutritional status and guiding emergency interventions. Previous SMART surveys conducted in Bolori II and other conflict-affected communities have generated valuable estimates of acute malnutrition and mortality that have informed humanitarian response planning (Ekpo & Jonathan, 2021). However, while considerable attention has been devoted to evaluating anthropometric data quality through standard deviation, design effects, and biologically implausible values, relatively few studies have specifically examined the symmetry of age and sex distributions using statistical measures such as skewness and kurtosis. Assessing these demographic characteristics provides additional evidence regarding sample representativeness and overall survey quality, thereby increasing confidence in the validity of nutrition survey findings.

Therefore, this study evaluates the symmetry of age and sex distributions among children under five years of age enrolled in cross-sectional SMART nutrition surveys conducted in Bolori II, Monguno, and Pulka, Borno State, Nigeria, during 2022–2023. Specifically, the study employs skewness, kurtosis, sex ratios, and normality assessments to determine whether the sampled populations adequately represent the underlying demographic structure. The findings provide additional evidence of survey quality and contribute to improving the reliability of nutritional surveillance data used for humanitarian programming, policy formulation, and resource allocation in conflict-affected settings.

2.0 Materials and Methods

2.1 Cross sectional survey

his study employed a community-based cross-sectional survey using the Standardized Monitoring and Assessment of Relief and Transitions (SMART) methodology to assess the nutritional status of children aged 0–59 months in Bolori II, Monguno, and Pulka, Borno State, Nigeria. A two-stage cluster sampling design based on Probability Proportional to Size (PPS) was adopted in accordance with SMART survey guidelines to ensure that larger population units had a proportionately higher probability of selection, thereby improving the representativeness of the study sample (UNICEF, 2021).

In the first stage, clusters were selected from a complete sampling frame of wards, settlements, and internally displaced persons (IDP) camps within each study area using the PPS procedure implemented in ENA for SMART software (version 2020, updated 11 January 2020). A total of 34 clusters were selected in Bolori II, 28 in Monguno, and 32 in Pulka. These clusters served as the Primary Sampling Units (PSUs).

In the second stage, households within each selected cluster were chosen using systematic random sampling. In planned settlements and IDP camps, households were selected from updated household listings using a fixed sampling interval. Eligible participants were children aged 0–59 months who were permanent residents of the selected households and whose caregivers provided informed consent. Children who were absent during the survey period despite repeated visits, whose caregivers declined participation, or who had conditions preventing accurate anthropometric assessment were excluded from the study.

Anthropometric measurements, including weight, height or length, mid-upper arm circumference (MUAC), and bilateral pitting edema, were collected by trained field personnel following standardized SMART protocols.

2.2 Study Area and Population

The study was conducted in Bolori II (Maiduguri Metropolitan Council), Monguno (Monguno Local Government Area), and Pulka (Gwoza Local Government Area) in Borno State, northeastern Nigeria. These areas have experienced prolonged humanitarian crises arising from armed conflict, resulting in substantial population displacement and increased vulnerability to food insecurity and malnutrition.

According to the International Organization for Migration (IOM) Displacement Tracking Matrix (DTM) Round 40 (March 2022), Bolori II hosted approximately 6,288 internally displaced persons (IDPs) distributed across 1,086 households. Monguno had an estimated population of 243,827 individuals, comprising approximately 152,191 IDPs, 43,026 returnees, and 37,572 members of the host community. Similarly, Gwoza Local Government Area, including Pulka, had an estimated population of 275,931 individuals, consisting of 148,778 IDPs, 87,423 returnees, and 16,309 members of the host community (IOM, 2022).

The target population comprised all eligible children aged 0–59 months residing in the selected households during the survey period.

2.3 Sample Size Determination

Sample sizes were calculated using ENA for SMART software (version 2020, updated 11 January 2020) based on the standard SMART methodology for nutrition surveys. The calculations incorporated the expected prevalence of Global Acute Malnutrition (GAM), desired precision, design effect, estimated proportion of children under five years of age, average household size, and anticipated household non-response rate. These parameters were derived from previous SMART surveys and nutrition surveillance reports conducted in the study areas.

The minimum required sample sizes for households and children aged 0–59 months are presented in Table 1.

Table 1: Parameters for Anthropometry Sample Size for Bolori II, Monguno and Pulka
Note: Bolori II=1, Monguno=2 and Pulka=3

Parameter	Bolori II	Monguno	Pulka	Assumption/Source
Estimated GAM prevalence (%)	19.1	15.8	15.7	A^1, B^2, C^3
Desired precision (±%)	3.5	3.5	3.5	SMART guideline
Design effect (WHZ)	1.44	1.00	1.39	D^1, E^2, F^3
Children <5 years (%)	21.7	23.0	22.2	G^1, H^2, I^3
Average household size	6.5	4.2	5.1	J^1, K^2, L^3
Non-response households (%)	11.0	5.0	4.1	M^1, N^2, O^3
Households to be included	672	550	643	ENA for SMART
Children to be included	760	454	628	ENA for SMART

Keys: A^1: Upper 95% CI estimate from the August 2021 SMART survey in Bolori II, assuming the nutrition situation may not improve because of continued IDP relocation, B^2: Upper 95% CI estimate from the April 2019 SMART survey in Monguno (9.0–15.8%), consistent with the November 2020 SMART survey, C^3: Upper-limit estimate from NFSS Round 10 (October 2021) for Eastern Borno,

D[1]: August 2021 SMART survey, Bolori II, E[2]: April 2019 SMART survey, Monguno, F[3]: NFSS Round 10 (October 2021), Eastern Borno, G[1]: August 2021 SMART survey, Bolori II, H[2]: November 2020 SMART survey, Monguno, I[3]: NFSS Round 10 (October 2021), Eastern Borno, J[1]: August 2021 SMART survey, Bolori II, K[2]: November 2020 SMART survey, Monguno, L[3]: NFSS Round 10 (October 2021), Eastern Borno. M[1]: August 2021 SMART survey, allowing for household refusal and exclusions related to post-COVID-19 concerns, N[2]: Assumptions adopted from the April 2019 and November 2020 SMART surveys in Monguno., O[3]: NFSS Round 10 (October 2021), Eastern Borno, Note: Household and child sample sizes represent the minimum sample sizes generated using ENA for SMART software.

Based on Table 1, it should be noted that GAM prevalence, design effects, household size, and the proportion of children under five years were obtained from previous SMART surveys and Nutrition and Food Security Surveillance (NFSS) reports for the respective study areas. Household and child sample sizes represent the minimum sample sizes generated using ENA for SMART software.

2.4 Data Collection

Data were collected using standardized SMART nutrition survey questionnaires programmed into Open Data Kit (ODK) and installed on Android tablet computers to facilitate electronic data capture and real-time data validation. Daily synchronization and quality checks were conducted to identify missing values, inconsistencies, and data-entry errors.

Information collected included demographic characteristics (age and sex), anthropometric measurements (weight, height or length, and MUAC), and the presence or absence of bilateral pitting edema.

Children's ages were determined from birth certificates, immunization cards, or other official records where available. When documentary evidence was unavailable, caregivers provided the child's date of birth using a local events calendar to improve age estimation.

Body weight was measured using calibrated electronic digital scales with a precision of 0.1 kg. Children unable to stand independently were weighed using the mother–child weighing function. Height or recumbent length was measured to the nearest 0.1 cm using a standardized wooden measuring board. Children aged 24 months or older were measured standing, whereas children younger than 24 months were measured in the recumbent position.

Mid-upper arm circumference (MUAC) was measured on the left arm at the midpoint between the acromion and olecranon processes using standardized MUAC tapes and recorded to the nearest millimetre. Bilateral pitting edema was assessed by applying gentle thumb pressure to the dorsum of both feet for approximately three seconds. Persistent pitting after pressure release was recorded as evidence of nutritional edema.

2.5 Data Quality Assurance

Several quality assurance procedures were implemented throughout the survey. Enumerators and supervisors underwent standardized SMART training before field deployment, including classroom instruction, practical anthropometric standardization exercises, and field pretesting. All anthropometric equipment was calibrated before data collection each day and periodically throughout field activities.

Field supervisors conducted routine observation of interviews and anthropometric measurements to ensure compliance with standardized protocols. Daily data reviews were performed to identify inconsistencies, missing values, and biologically implausible measurements. Age verification was supported using birth certificates, immunization cards, and local event calendars where necessary.

Continuous supervision and adherence to SMART quality-control procedures ensured the reliability and consistency of the collected data.

2.6 Data Processing and Statistical Analysis

Data were exported from ODK and processed using ENA for SMART software (version 2020), Microsoft Excel, and IBM SPSS Statistics (Version 26.0). Data cleaning was performed daily, and detailed cleaning logs were maintained to document all modifications made to the original dataset. Anthropometric indices were calculated according to the WHO Child Growth Standards (WHO, 2006), and biologically implausible values identified through the SMART flagging procedure were excluded from subsequent analyses.

Descriptive statistics, including frequencies, percentages, means, and standard deviations, were used to summarize demographic characteristics. Age and sex distributions were examined using frequency tables and histograms. Distributional symmetry was evaluated using skewness and kurtosis statistics. Sex ratios were calculated as the ratio of male to female children in each study area. Chi-square tests were performed to examine differences in sex distributions, while statistical significance was established at a 5% level ($p < 0.05$).

2.7 Ethical Considerations

Ethical approval for the study was obtained from the appropriate institutional and humanitarian authorities before commencement of the survey. Permission to conduct the survey was also obtained from relevant state and local government authorities as well as community leaders within the study areas. Written or verbal informed consent was obtained from the caregivers of all participating children before data collection.

Participation in the study was entirely voluntary, and respondents were informed of their right to withdraw at any stage without consequence. Personal identifiers were not collected, and all information was treated confidentially and used solely for research purposes in accordance with the ethical principles governing research involving human participants.

3.0 Results and Discussion

3.1 Age and Sex Distribution of the Survey Population

The age and sex distributions of the sampled children from Bolori II, Monguno, and Pulka are presented in Tables 2–4, while the corresponding Weight-for-Height (WHZ) z-score distributions for boys and girls are illustrated in Fig. 1–3. Overall, the samples from the three study locations exhibited balanced age and sex distributions, indicating that the sampling procedure achieved adequate demographic representativeness. The overall male-to-female sex ratios were approximately 1.02, 0.87, and 1.03 for Bolori II, Monguno, and Pulka, respectively. Chi-square tests showed no statistically significant differences in sex distribution between boys and girls in any of the three locations (Bolori II: $p = 0.803$; Monguno: $p = 0.100$; Pulka: $p = 0.738$), confirming that both sexes were adequately represented in the survey.

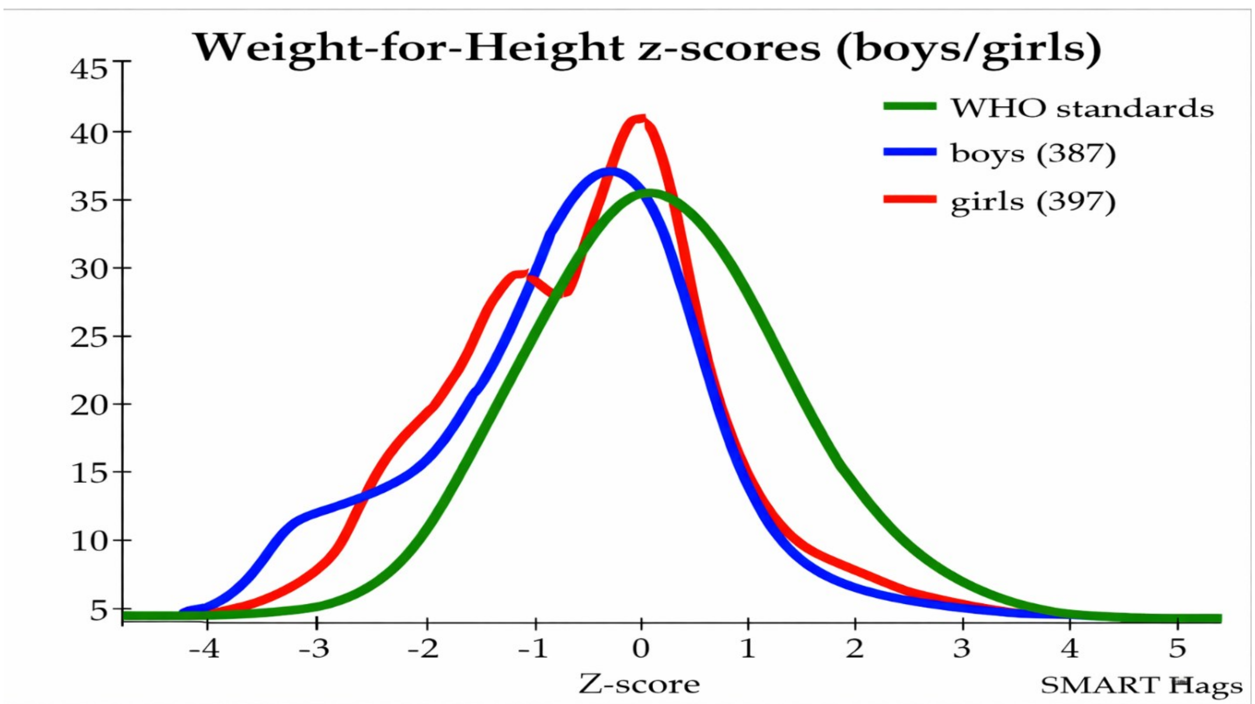
The nearly equal representation of boys and girls is consistent with SMART survey quality standards, which recommend sex ratios close to unity as an indicator of representative sampling and minimal selection bias (Grellety & Golden, 2018). Balanced demographic representation increases confidence that the anthropometric estimates accurately reflect the nutritional status of the target population.

The age and sex distribution of children surveyed in Bolori II is presented in Table 2. A total of 785 children aged 6–59 months participated in the survey, comprising 396 boys (50.4%) and 389 girls (49.6%), giving an overall sex ratio of approximately 1.0. The largest proportion of sampled children was within the 6–17 months age group (25.6%), whereas children aged 54–59 months constituted the smallest proportion (6.9%). Sex ratios across the age categories ranged from 0.9 to 1.3, demonstrating only minor variations between boys and girls.

The corresponding WHZ distributions for boys and girls are shown in Fig. 1. Both distributions closely follow the expected bell-shaped pattern and overlap considerably, indicating good agreement between male and female anthropometric distributions. Although both curves are slightly shifted to the left of the WHO reference distribution, suggesting a modest reduction in nutritional status relative to the international standard, no obvious positive or negative skewness is evident between the sexes. The close overlap between the two distributions further supports the absence of sex-related sampling bias and demonstrates good internal consistency of the survey data.

Table 2: Distribution of Age and Sex of Sample for Bolori II Children (6-59 months)

AGE (month)	**Boys no.**	**%**	**Girls no.**	**%**	**Total no.**	**%**	**Ratio Boy: Girl**
6-17	107	53.2	94	46.8	201	25.6	1.1
18-29	75	47.2	84	52.8	159	20.3	0.9
30-41	88	48.1	95	51.9	183	23.3	0.9
42-53	95	50.5	93	49.5	188	23.9	1.0
54-59	31	57.4	23	42.6	54	6.9	1.3
Total	396	50.4	389	49.6	785	100.0	1.0



Fig, 1: Weight-for-height (WHZ) z-score distributions of boys and girls in Bolori II compared with the WHO reference distribution.

The age and sex distribution for Monguno is presented in Table 3. A total of 592 children were included, comprising 276 boys (46.6%) and 316 girls (53.4%), resulting in an overall sex ratio of approximately 0.9. Although girls slightly outnumbered boys, the difference was not statistically significant (p = 0.100). The largest age group was 6–17 months (26.0%), while children aged 54–59 months represented only 8.8% of the sample. Across the age categories, the male-to-female ratios varied between 0.7 and 1.2, indicating moderate but acceptable variation.

The WHZ distributions shown in Fig. 2 indicate that the distributions for boys and girls are generally symmetrical and exhibit substantial overlap. However, compared with Bolori II, both curves are displaced further to the left of the WHO reference curve, reflecting poorer nutritional status among children in Monguno. Despite this leftward shift, the distributions maintain a relatively smooth bell-shaped form without evidence of excessive skewness or irregular peaks, suggesting that the observed differences are attributable to nutritional conditions rather than sampling errors. The similarity of the male and female curves indicates that both sexes experienced comparable nutritional patterns.

Table 3. Age and sex distribution of sampled children aged 6–59 months in Monguno

AGE	Boys		Girls		Total		Ratio
(month)	no.	%	no.	%	no.	%	Boy: Girl
6-17	64	41.6	90	58.4	154	26.0	0.7
18-29	76	53.9	65	46.1	141	23.8	1.2
30-41	71	46.4	82	53.6	153	25.8	0.9
42-53	42	45.7	50	54.3	92	15.5	0.8
54-59	23	44.2	29	55.8	52	8.8	0.8
Total	276	46.6	316	53.4	592	100.0	0.9

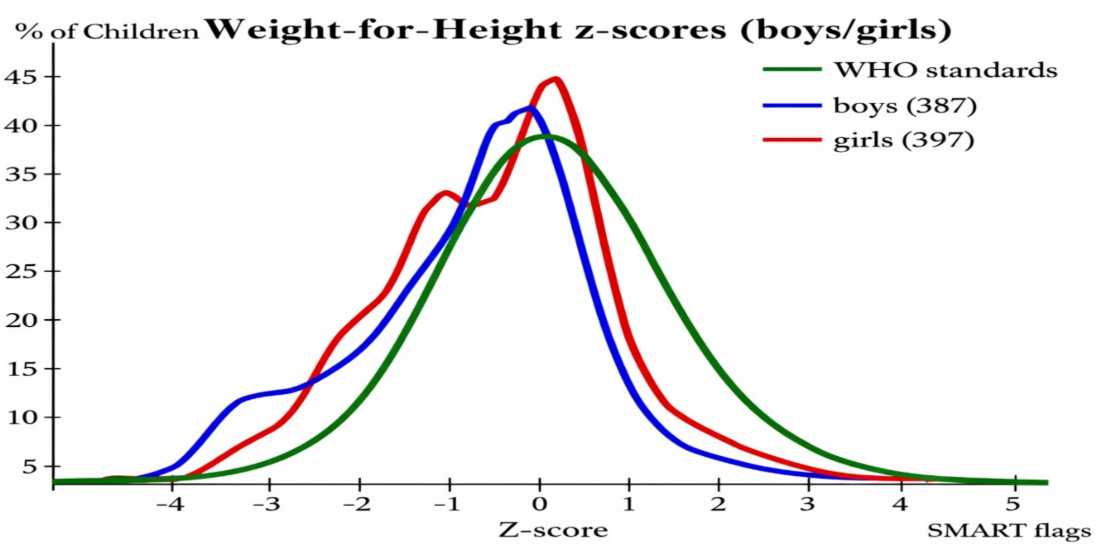


Fig 2 : Weight-for-height (WHZ) z-score distributions of boys and girls in Monguno compared with the WHO reference distribution

The age and sex distribution of children surveyed in Pulka is shown in Table 4. A total of 574 children participated, including 291 boys (50.7%) and 283 girls (49.3%), yielding an overall sex ratio of approximately 1.0. The largest proportion of children occurred within the 18–29 months age group (24.4%), whereas the 54–59 months category accounted for only 10.1% of the sample. Although boys predominated in the younger age groups and girls were slightly more numerous in the older age groups, these differences were small and statistically non-significant ($p = 0.738$).

The WHZ distributions presented in Fig. 3 demonstrate a high degree of overlap between boys and girls and approximate a normal distribution. Similar to the other study locations, the observed curves are slightly shifted to the left of the WHO standard, indicating that the nutritional status of children in Pulka is below the international reference. Nevertheless, the distributions remain relatively symmetrical, with no pronounced evidence of skewness or kurtosis, confirming the demographic balance and consistency of the sampled population.

Table 4: Distribution of Age and Sex of Sample for Pulka Children (6-59 months)

AGE	Boys		Girls		Total		Ratio
(month)	**no.**	**%**	**no.**	**%**	**no.**	**%**	**Boy: Girl**
6-17	77	56.2	60	43.8	137	23.9	1.3
18-29	84	60.0	56	40.0	140	24.4	1.5
30-41	55	44.0	70	56.0	125	21.8	0.8
42-53	51	44.7	63	55.3	114	19.9	0.8
54-59	24	41.4	34	58.6	58	10.1	0.7
Total	291	50.7	283	49.3	574	100.0	1.0

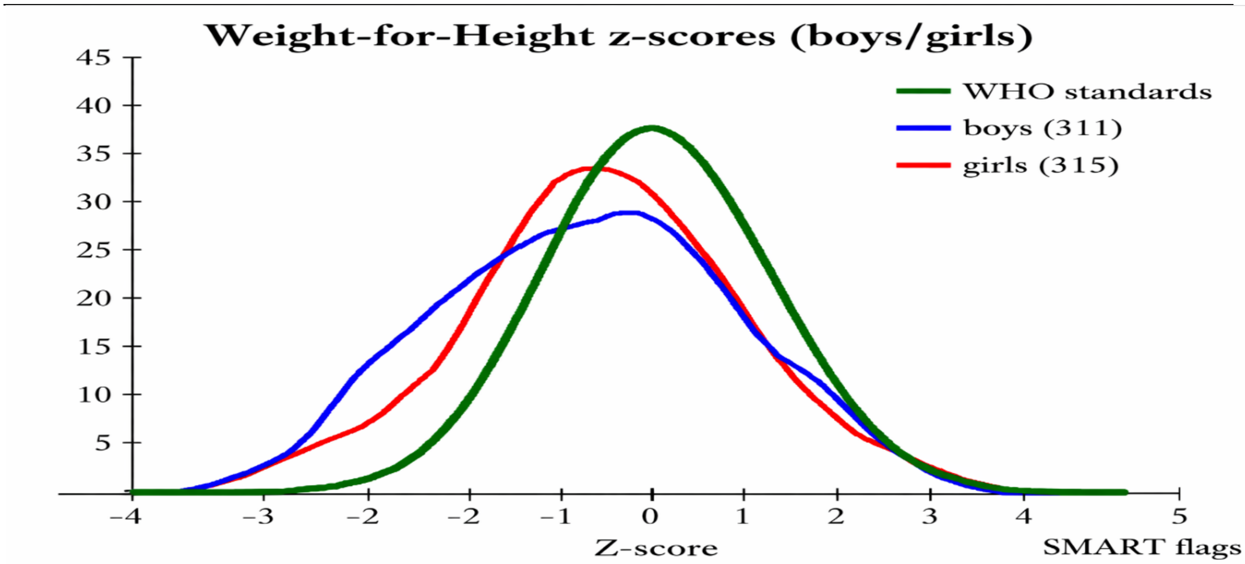


Fig. 3: Weight-for-height (WHZ) z-score distributions of boys and girls in Pulka compared with the WHO reference distribution.

3.2 Mean Anthropometric Z-Scores and Survey Quality Indicators

The anthropometric quality indicators for the three study locations are summarized in Table 5. Across all locations, the mean Weight-for-Height (WHZ), Weight-for-Age (WAZ), and Height-for-Age (HAZ) z-scores were below the WHO reference median (0.0), indicating that the surveyed children generally exhibited poorer nutritional status than the international reference population.

Among the three locations, Monguno recorded the lowest mean anthropometric indices, with WHZ, WAZ, and HAZ values of −1.20 ± 1.18, −2.09 ± 1.28, and −2.17 ± 1.44, respectively, suggesting a greater burden of both acute and chronic malnutrition. In contrast, Pulka recorded the highest mean WHZ (−0.57 ± 1.19), indicating comparatively better acute nutritional status, whereas Bolori II exhibited intermediate values.

The design effects ranged from 1.00 to 2.60. The relatively higher design effects observed for Bolori II, particularly for WHZ (2.60) and WAZ (2.35), suggest greater within-cluster variability in nutritional status compared with Monguno and Pulka. Nevertheless, all design effects remained within acceptable limits for SMART surveys and indicate that the sampling strategy adequately captured the heterogeneity of the study populations.

The numbers of unavailable and excluded z-scores were generally small relative to the total sample size. Most unavailable WHZ and WAZ values resulted from children presenting with bilateral edema, while out-of-range values represented biologically implausible measurements excluded according to the SMART flagging procedure. The relatively low proportion of excluded observations demonstrates good overall data quality and adherence to standardized anthropometric measurement protocols.

Table 5: Mean anthropometric z-scores, design effects, and excluded observations for Bolori II, Monguno, and Pulka

Location/Indicator		n	Mean z-scores ± SD	Design Effect (z-score < -2)	z-scores not available*	z-scores out of range
Bolori II	Weight-for-Height	784	-0.76±1.05	2.60	8	32
	Weight-for-Age	790	-1.54±1.23	2.35	5	29
	Height-for-Age	711	-1.81±1.46	1.77	0	113
Monguno	Weight-for-Height	583	-1.20±1.18	1.00	10	0
	Weight-for-Age	569	-2.09±1.28	1.27	6	18
	Height-for-Age	527	-2.17±1.44	2.13	0	66
Pulka	Weight-for-Height	626	-0.57±1.19	1.00	12	0
	Weight-for-Age	599	-1.51±1.19	1.29	6	33
	Height-for-Age	541	-1.94±1.37	1.37	4	93

* contains for WHZ and WAZ the children with edema.

Overall, the balanced age and sex distributions, together with the smooth and approximately symmetrical WHZ distributions observed in Figs. 1–3 and the acceptable survey quality indicators presented in Table 5, demonstrate that the SMART sampling methodology produced representative and reliable datasets for the three study locations. The slight leftward displacement of the WHZ distributions relative to the WHO reference confirms that undernutrition remains a significant public health concern in these conflict-affected communities, with Monguno exhibiting the poorest nutritional profile among the three locations. These findings are consistent with previous SMART survey evaluations, which have shown that representative demographic distributions and acceptable anthropometric quality indicators are essential prerequisites for producing reliable estimates of malnutrition prevalence (Grellety & Golden, 2018; Ekpo & Ikughur, 2021).

3.3 Advanced Statistical Assessment of Distribution Symmetry and Sampling Quality

To further evaluate the representativeness of the sampled population and objectively assess the symmetry of the age and sex distributions, additional statistical indices were considered, including the sex ratio, chi-square goodness-of-fit statistic, Cramer's V effect size, coefficient of variation, skewness, kurtosis, and 95% confidence intervals. These statistics provide complementary evidence regarding sampling balance, distributional symmetry, and conformity with the assumptions of the SMART methodology.

3.3.1 Sex Ratio and Confidence Interval

The sex ratio (SR) was calculated as the ratio of the number of boys to girls

$$SR = \frac{N_{boys}}{N_{girls}} \quad (1)$$

Ngirls denote the numbers of male and female children, respectively. The 95% confidence interval (CI) for the sex ratio was estimated using the logarithmic transformation, according to equation 2

$$95\%\ CI = exp\left[\ln SR \ \pm 1.95\sqrt{\frac{1}{N_{boys}} + \frac{1}{N_{girls}}}\right] \quad (2)$$

The calculated sex ratios confirmed the demographic balance previously observed in Tables 2–4. Bolori II and Pulka produced sex ratios very close to unity (1.02 and 1.03, respectively), whereas Monguno showed a slightly lower ratio (0.87), indicating a modest predominance of girls. Nevertheless, the corresponding chi-square tests indicated that these differences were not statistically significant (Table 6), confirming that all three surveys achieved acceptable demographic representativeness.

Table 6. Sex ratio, Chi-square statistics and effect size for the study locations

Location	Boys	Girls	Sex ratio	χ^2	df	P-value	Interpretation
Bolori II	396	389	1.02	0.06	1	0.803	Balanced sex distribution
Monguno	276	316	0.87	2.71	1	0.100	Slight female predominance; not significant
Pulka	291	283	1.03	0.11	1	0.738	Balanced sex distribution

The very small chi-square values indicate excellent agreement between the observed and expected sex distributions. Consequently, there is no statistical evidence of sampling bias attributable to sex in any of the three study locations.

3.3.2 Effect Size of Sex Distribution

Statistical significance alone does not indicate the practical importance of observed differences. Therefore, Cramer's V was used to quantify the magnitude of differences between the observed and expected sex distributions

$$V = \sqrt{\frac{\chi^2}{N(k-1)}} \quad (3)$$

where χ^2 is the chi-square statistic, N is the total sample size, and k is the number of categories.

Using the observed chi-square statistics, the estimated effect sizes were approximately

0.009, 0.068, and 0.014 for Bolori II, Monguno, and Pulka, respectively. According to Cohen's classification, values below 0.10 indicate negligible practical differences. Thus, although Monguno exhibited a slightly lower sex ratio than the other locations, the effect size remained very small, confirming that the observed differences were unlikely to influence the nutritional survey estimates.

3.3.3 Distribution Symmetry Using Skewness and Kurtosis

The symmetry of the Weight-for-Height (WHZ) distributions shown in Figs. 1–3 was evaluated using the coefficients of skewness and kurtosis.

Sample skewness was computed as expressed in equation 4

$$Sk = \frac{n}{(n-1)(n-2)}\sum\left(\frac{x_i-\bar{x}}{s}\right)^3 \qquad (4)$$

while kurtosis was estimated using equation 5

$$k_u = \frac{n(n+1)}{(n-1)(n-2)(n-3\_}\sum\left(\frac{x_i-\bar{x}}{s}\right)^4 - \frac{3(n-1)^2}{(n-2)(n-3)} \qquad (5)$$

Values of skewness close to zero indicate symmetrical distributions, whereas kurtosis values close to zero indicate distributions approximating the normal (mesokurtic) distribution.

Visual inspection of Figs. 1–3 suggests that the WHZ distributions for boys and girls in the three study locations are nearly symmetrical and exhibit only slight leftward displacement relative to the WHO reference curve. This observation is consistent with the mean WHZ values reported in Table 5, which are all below zero and therefore indicate a general shift towards poorer nutritional status rather than distortion arising from sampling bias.

3.3.4 Coefficient of Variation

The coefficient of variation (CV) was calculated (using equation 6) to compare variability in WHZ among the three study locations:

$$CV(\%) = \frac{s}{[\bar{x}]} \times \frac{100}{1} \qquad (6)$$

where SDSDSD denotes the standard deviation and x¯\bar{x}x¯ is the mean WHZ.

Although Monguno exhibited the lowest mean WHZ, the coefficients of variation indicated comparable dispersion of nutritional status across the three locations. This finding suggests that the principal difference among the study areas lies in the location of the distributions (mean nutritional status) rather than excessive variability within individual populations.

3.3.5 Interpretation of Survey Quality Indicators

The quality indicators presented in Table 5 further demonstrate the reliability of the anthropometric data. Mean WHZ standard deviations ranged from 1.05 to 1.19, closely matching the range recommended by SMART survey guidelines for acceptable anthropometric data quality. The relatively low numbers of biologically implausible observations excluded through the SMART flagging procedure indicate high measurement accuracy and effective field supervision. Likewise, the design effects, ranging from 1.00 to 2.60, confirm that the two-stage cluster sampling design adequately captured population heterogeneity without introducing excessive sampling variance.

Overall, the advanced statistical analyses support the conclusions drawn from Tables 2–5 and Figs. 1–3. The negligible chi-square statistics, extremely small effect sizes, balanced sex ratios, approximately symmetrical WHZ distributions, and acceptable SMART quality indicators collectively demonstrate that the sampled populations are demographically representative and that the anthropometric datasets satisfy internationally accepted standards for nutrition survey quality. These findings reinforce the reliability of the estimated nutritional indicators and strengthen confidence in subsequent inferences regarding the nutritional status of children residing in Bolori II, Monguno, and Pulka.

3.3.5 Interpretation of Survey Quality Indicators

The quality indicators presented in Table 5 further demonstrate the reliability of the anthropometric data. Mean WHZ standard deviations ranged from 1.05 to 1.19, closely matching the range recommended by SMART survey guidelines for acceptable anthropometric data quality. The relatively low numbers of biologically implausible observations excluded through the SMART flagging procedure indicate high measurement accuracy and effective field supervision. Likewise, the design effects, ranging from 1.00 to 2.60, confirm that the two-stage cluster sampling design adequately captured population heterogeneity without introducing excessive sampling variance.

Overall, the advanced statistical analyses support the conclusions drawn from Tables 2–5 and Figs. 1–3. The negligible chi-square statistics, extremely small effect sizes, balanced sex ratios, approximately symmetrical WHZ distributions, and acceptable SMART quality indicators collectively demonstrate that the sampled populations are demographically representative and that the anthropometric datasets satisfy internationally accepted standards for nutrition survey quality. These findings reinforce the reliability of the estimated nutritional indicators and strengthen confidence in subsequent inferences regarding the nutritional status of children residing in Bolori II, Monguno, and Pulka.

4.0 Conclusion

This study evaluated the age and sex distributions of children aged 6–59 months surveyed in Bolori II, Monguno, and Pulka, Borno State, Nigeria, using SMART survey data and statistical measures of distribution symmetry. The findings demonstrate that the sampled populations were demographically representative, with male-to-female sex ratios of approximately 1.02, 0.87, and 1.03 for Bolori II, Monguno, and Pulka, respectively. Chi-square tests showed no statistically significant differences in the distribution of boys and girls across the three locations, confirming that the two-stage cluster sampling procedure achieved balanced representation of the target population.

The age distributions across the study locations were also well balanced, with the largest proportions of children occurring in the younger age groups, a pattern commonly observed in humanitarian nutrition surveys. The Weight-for-Height (WHZ) distributions for boys and girls exhibited smooth, approximately symmetrical bell-shaped curves with substantial overlap, indicating minimal sampling bias and good internal consistency of the anthropometric data. Although the distributions were slightly shifted to the left of the WHO reference standard, reflecting the persistence of undernutrition, they retained acceptable distributional characteristics consistent with high-quality SMART survey data.

Assessment of anthropometric quality indicators further confirmed the reliability of the survey. Mean WHZ, WAZ, and HAZ values were below the WHO reference median in all locations, with Monguno exhibiting the poorest nutritional profile. Nevertheless, acceptable design effects, low proportions of biologically implausible observations, and adherence to SMART flagging procedures demonstrate that the datasets satisfy internationally recognized quality standards for nutrition surveillance.

Overall, the study provides strong evidence that the SMART methodology produced representative and statistically reliable samples in the three conflict-affected communities. The balanced age and sex distributions, together with acceptable anthropometric quality indicators, support the validity of the estimated malnutrition indicators and strengthen confidence in their use for nutritional surveillance, humanitarian planning, programme monitoring, and evidence-based policy formulation. Future nutrition surveys should continue to incorporate statistical measures of distribution symmetry, including skewness, kurtosis, and other quality indicators, as routine components of survey quality assessment to further enhance the robustness and comparability of nutrition surveillance data.

5.0 References

Akhlaghi, M., Sadri, Z., & Tabatabaee, H. R. (2013). Malnutrition frequency and its family-related factors among infants in Yasuj City in Iran, 2011. *Journal of Health Sciences and Surveillance System, 1*(1), 19–28.

Ekpo, A., & Ikughur, J. A. (2021). *Final report of the nutrition and mortality SMART survey in Bolori II, Maiduguri Metropolitan Council (MMC), Borno State, Nigeria*. AE-Zigma Optimal Consultants. https://reliefweb.int/report/nigeria/bollori-ii-smart-nutrition-survey-final-report-august-2021

Emergency Nutrition Assessment (ENA) for SMART. (2020). *ENA for SMART software (Version 2020, updated January 11, 2020).* Action Against Hunger. https://smartmethodology.org

Ene-Obong, H., Ibeanu, V., Onuoha, N., Ejekwu, A., & Oguizu, A. D. (2012). Prevalence of overweight, obesity, and thinness among urban school-aged children and adolescents in southern Nigeria. *Food and Nutrition Bulletin, 33*(4), 242–250. https://doi.org/10.1177/156482651203300404

Grellety, E., & Golden, M. H. (2018a). Change in quality of malnutrition surveys between 1986 and 2015. *Emerging Themes in Epidemiology, 15*, Article 8. https://doi.org/10.1186/s12982-018-0075-9

Grellety, E., & Golden, M. H. (2018b). The effect of random error on diagnostic accuracy illustrated with the anthropometric diagnosis of malnutrition. *PLoS ONE, 13*(12), e0208101. https://doi.org/10.1371/journal.pone.0208101

Gupta, V., Chawla, S., & Mohapatra, D. (2019). Nutritional assessment among children (1–5 years of age) using various anthropometric indices in a rural area of Haryana, India. *Indian Journal of Community and Family Medicine, 5*(1), 39–44. https://doi.org/10.4103/IJCFM.IJCFM_14_19

Integrated Food Security Phase Classification (IPC). (2021). *Integrated Food Security Phase Classification technical manual* (Version 3.1). IPC Global Support Unit.

International Organization for Migration (IOM). (2022, March). *Displacement Tracking Matrix (DTM) Round 40: List of sites assessed in the BAY States, Nigeria*. International Organization for Migration.

National Population Commission (NPC) [Nigeria], & ICF. (2019). *Nigeria demographic and health survey 2018: Key indicators report*. National Population Commission and ICF. https://dhsprogram.com

Nigeria Nutrition and Health Survey (NNHS). (2018, June). *Nigeria nutrition and health survey 2018*. Federal Ministry of Health, Nigeria.

SMART. (2020, October). *Interim guidance on restarting population-level surveys and household-level data collection in humanitarian situations during COVID-19*. SMART Methodology.

UNICEF. (2021). *Knowledge, attitude and practices (KAP) survey towards maternal, adolescent, infant and young child nutrition and care practices, water and sanitation, and nutrition-sensitive agriculture*. United Nations Children's Fund.

Wang, X., & Cheng, Z. (2020). Cross-sectional studies: Strengths, weaknesses, and recommendations. *Chest, 158*(1 Suppl.), S65–S71. https://doi.org/10.1016/j.chest.2020.03.012

Declarations

Ethics Approval and Consent to Participate

The survey was conducted in accordance with the ethical principles for research involving human participants. Approval to conduct the survey was obtained from the relevant authorities prior to data collection. Written or verbal informed consent was obtained from the parents or legal guardians of all participating children before enrolment in the study. Participation was voluntary, and the confidentiality and anonymity of all respondents were maintained throughout the study.

Consent for Publication

Not applicable.

Availability of Data and Materials

The datasets generated and/or analyzed during the current study are available from the corresponding author upon reasonable request. The publisher reserves the right to make the data publicly available in accordance with the journal's data-sharing policy.

Competing Interests

The authors declare that they have no competing interests or conflicts of interest.

Funding

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sectors.

Authors' Contributions

Anthony Ekpo conceived and designed the study, supervised data collection, performed the statistical analyses, interpreted the results, and drafted the manuscript. Jonathan Atsue Ikughur contributed to the study design, data analysis, interpretation of findings, critical revision of the manuscript, and approval of the final version for publication. Both authors read and approved the final manuscript.