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On the Gaussian Distribution of Age and Sex in a Nutritional Survey in Hong and Michika

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Abstract: *This study evaluates the Gaussian distributions of age and sex nutrition survey conducted among children under fives in Hong and Michika areas of Adamawa State, in 2024. All the prevalence rates for the two locations as considered in this survey were based on the exclusion of z-scores from observed mean SMART flags: WHZ -3 to 3; HAZ -3 to 3; and WAZ -3 to 3. However, the tables showing the summary statistics of all the children (0-59) months were presented and enumerated and are distributed evenly, as corroborated where the sex curves mimics the Gaussian curve, with an overall sex ratio of 0.7 for Hong as against the 0.9 in Michika, an indication of adequacy in sex ratio for Michika. However, with a as dis-aggregated age and sex, an overall sex ratio (male/female) had the p-value = 0.761 and 0.826 for Hong and Michika respectively; indicating a sample with equal representation of boys and girls.*

Keyword: *Gaussian distribution, nutrition survey, exclusion of z-scores, observed mean, sex curves, P-value.*

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1.0 Introduction

The quality of anthropometric nutrition surveys depends not only on the accuracy of body measurements but also on the demographic composition of the sampled population. Age and sex are among the most fundamental variables in population studies because they determine the structure of human populations and strongly influence the interpretation of health and nutritional outcomes. These demographic variables affect fertility, mortality, migration, growth patterns, disease occurrence, and nutritional status, making them indispensable in the design, implementation, and interpretation of nutrition surveys (Poston & Bouvier, 2010). Consequently, evaluating the distribution of age and sex within a survey sample provides an important indication of sampling quality and representativeness.

One of the most common sources of error in nutritional surveys is **age heaping**, the tendency of respondents to report children's ages at preferred digits or rounded intervals. Age heaping often introduces systematic bias into anthropometric indicators because nutritional indices such as Weight-for-Height (WHZ), Height-for-Age (HAZ), and Weight-for-Age (WAZ) are age-dependent. To minimize this problem, nutritional anthropometry commonly groups children into standardized age categories of 0–5, 6–23, 24–35, 36–47, and 48–59 months. Examination of age and sex distributions within these categories is therefore an essential component of data quality assessment in SMART nutrition surveys (Myatt, 2020).

Gaussian (normal) distribution provides one of the most widely accepted statistical models for evaluating biological and anthropometric measurements. A Gaussian distribution is characterized by symmetry around the mean and is completely described by its mean (μ) and standard deviation (σ). Approximately 68.3%, 95.4%, and 99.7% of observations lie within one, two, and three standard deviations of the mean, respectively. Because most anthropometric variables in healthy populations approximate a normal distribution, deviations from Gaussianity may indicate sampling bias, measurement errors, digit preference, age misreporting, or true nutritional abnormalities (Grellety & Golden, 2016).

Within the SMART methodology, the assessment of Gaussian distribution has become a standard approach for evaluating survey quality. SMART flags exclude biologically implausible anthropometric observations using predefined limits, thereby improving the reliability of prevalence estimates for wasting, stunting, and underweight. Comparative evaluations of more than three decades of nutritional surveys demonstrated that the adoption of SMART flags has substantially improved data quality, reduced measurement errors, and produced anthropometric distributions that more closely resemble the WHO reference population (Grellety & Golden, 2018). Consequently, examination of the distribution of WHZ, HAZ, and WAZ serves not only as a measure of nutritional status but also as an important quality assurance procedure.

The World Health Organization recommends that the standard deviation of Weight-for-Height Z-scores should generally lie between 0.8 and 1.2 in high-quality surveys. Larger deviations often suggest poor measurement precision, sampling irregularities, or inaccurate age determination. For this reason, SMART survey reports routinely evaluate the shape, spread, kurtosis, skewness, and normality of anthropometric distributions before interpreting prevalence estimates of malnutrition (ENA for SMART, 2020).

Several recent studies have demonstrated that age and sex substantially influence nutritional characteristics across different populations. Dietary diversity has been shown to increase with age, while significant differences in dietary patterns exist between males and females, emphasizing the importance of age- and sex-specific analyses in nutritional assessments (Iizuka et al., 2025). Similarly, sex-specific associations between nutritional status and diabetic kidney disease have been reported among Chinese adults, indicating that nutritional indicators may have different predictive values for males and females (Han et al., 2025). Longitudinal evidence from Japan further showed that the effects of protein, fat, and carbohydrate intake on mortality differ significantly by sex, highlighting the biological importance of sex-disaggregated nutritional analyses (Hayashi et al., 2025).

Beyond biological differences, nutrition is also influenced by gender-related behavioural, psychological, and socioeconomic factors. Reviews have demonstrated that sex and gender affect dietary intake, food accessibility, nutritional requirements, and metabolic responses throughout the life course (Sbisà et al., 2025). Among adolescents, nutritional status is shaped by both shared and sex-specific determinants such as physical activity, dietary diversity, fast-food consumption, body image, and screen time, reinforcing the need for nutrition programmes that recognize demographic heterogeneity (Mekonen & Abebe, 2025). Likewise, psychological factors including loneliness, stress, boredom, and emotional eating have been shown to influence dietary behaviour among adolescents and young adults (Naidu et al., 2017).

Despite these advances, relatively few studies have investigated the Gaussian distribution of age and sex as indicators of data quality in humanitarian nutrition surveys conducted in conflict-affected settings. Most published studies have focused primarily on estimating the prevalence of wasting, stunting, or underweight without evaluating whether the underlying demographic distributions adequately represent the target population. For example, Legason and Dricile (2018) reported the prevalence of acute malnutrition among children aged 6–59 months in north-western Uganda but did not examine the statistical characteristics of age-sex distributions that underpin the anthropometric estimates. Consequently, there remains limited empirical evidence on the demographic quality of anthropometric datasets generated from SMART surveys in humanitarian contexts.

Hong and Michika Local Government Areas of Adamawa State have experienced repeated humanitarian crises arising from armed conflict, population displacement, food insecurity, and disruption of health services. These factors increase the risk of childhood malnutrition and underscore the need for reliable nutrition surveillance. Although SMART surveys have routinely been conducted in these areas, little information exists regarding the statistical distribution of age and sex among surveyed children and the implications of these distributions for assessing survey quality.

Therefore, this study evaluates the Gaussian distribution of age and sex among children aged 0–59 months included in the 2024 SMART nutritional survey conducted in Hong and Michika Local Government Areas of Adamawa State, Nigeria. Specifically, the study examines the age-sex composition of the sampled population, evaluates the normality of anthropometric Z-score distributions using SMART flags, and assesses whether the observed demographic characteristics satisfy internationally accepted indicators of high-quality nutrition survey data. The findings provide additional evidence on the reliability of anthropometric measurements obtained from humanitarian nutrition surveys and contribute to strengthening quality assurance procedures in future SMART assessments.

2.0 Materials and Methods

2.1 Cross-sectional survey

This study employed a cross-sectional survey procedure following the SMART methodology, using a two-stage cluster sampling technique based on Probability Proportional to Size (PPS), which is useful in Nutrition and Mortality surveys. This technique allowed for more representative sampling units from villages/wards with larger population sizes. It followed the usual methods for measuring MUAC, weight, height and age using well trained measurers according to the SMART guideline. The anthropometric measurements were taken from sampled children aged (0-59 months) and living in the targeted locations at the time of the survey. While the mortality interview included all members of eligible households selected randomly from the same cluster as that of nutrition and gave their consent to be interviewed.

2.2 Study area and population

The survey was conducted in Hong and Michika LGAs in Adamawa State in North-Eastern Nigeria. Adamawa state is in the North-East geopolitical zone of Nigeria, bordered by Borno to the northwest, Gombe to the west by about 95 km, and Taraba to the southwest by about 366 km, while its eastern border forms part of the national border with Cameroon across the Atlantika Mountains by about 712 km. Hong is in the domain of Northern Adamawa with an estimated population of about 289,790 and Michika is also in the domain of Northern Adamawa with an estimated population of about 221,702 in Northeast Nigeria according to the Nutrition Food Security Surveillance (NFSS) December 2023 LGA classification arrangement

2.3 Sample Size Calculation

The study population comprised all individuals identified in the two locations: Hong and Michika, at the first stage, 31 clusters for each of the two LGAs were selected randomly based on PPS using the table of assigning clusters on ENA for SMART 2020 (Jan 11, version) platform. The clusters are the Primary Sampling Unit (PSU) while the households are the Basic Sampling Units (BSU). The sample size for the Anthropometric survey was calculated as required and the minimum sample size for children aged 0-59 months in the Households returned using SMART+ which was corroborated by the 6-59 months HH sample size using ENA for SMART software (i.e., 413 multiplied by 0.9) as indicated in Tables 1.

The sample size (n) for the nutrition component of the survey was calculated based on a prior estimated prevalence of Global Acute Malnutrition (GAM) reflecting recent GAM estimates from the two locations, a desired precision, design effect and other relevant parameters were also extracted from related and recent literature.

2.4 Data collection

Data on the variables of interest, such as age, sex, edema and MUAC, were collected during the interview. Standardized questionnaires for nutrition and its needs assessment, as recommended for the Nutrition KAP survey, were coded in ODK (Open Data Kit) and formatted on Android smartphone tablets for each enumerator and were used for data collection and electronic entry, respectively. Daily data collected by each enumerator were subjected to quality checks. Age in months : A child's age in months was determined from the birth date by interviewing the mother or an adult member of the household, using mainly birth certificates or immunization cards, where available, or by using the vaccination card reporting the child's birth date. Height/Length: The height of a child (0-59 months) was measured bareheaded and barefooted with a wooden measuring board and reported with a precision of 0.1cm. Any child who is two years or more was measured in the upright position, while those less than two years were measured in the lying down position. Weight: The weight was measured with an electronic scale and reported with a precision of 0.1kg. The scale had a 2-in-1 (mother/child) function. MUAC measurement: Mid-Upper Arm Circumference was measured on the midway point of a child's (0-59 months) and women's (15-49 years) left arm using a standard measuring tape calibrated in cm, which was later converted to mm. Edema : Bilateral edema was diagnosed if an imprint was observed after 5 seconds of pressure with the thumb on the dorsum of both feet of an eligible child and was recorded as "yes" or "no".

2.5 Data Quality Assurance

Several procedures were used to control data quality throughout the process of the survey, including using skilled data collectors trained on standardized training material and a seasoned Nutrition expert who must have partaken in at least two Nutrition-related surveys within the last three years. Team supervisor/leader undertook proper calibrations/disinfection of the survey material before proceeding to the field and at intervals while in the field, close monitoring, manual checks, use of immunization card and birth certificate for age probing, reference forms/note for concordance, and use of cluster control and household selection forms for triangulation. The enumerators, too, were well motivated to ensure they did their work diligently without undue compromise.

2.6 Data Processing and Statistical Analysis

Collected datasets were cleaned and analyzed on ENA for SMART software version 2020 (updated on the 11th of January 2020), EXCEL, and SPSS platforms daily, and cleaning logs were maintained to track all changes from the original raw data. The results on malnutrition prevalence using MUAC were based on WHO 2006 growth standards.

Table 1: Parameters for Anthropometry Data Collection Plan for Hong and Michika

Parameters for Anthropometry	LGAs/Values		Assumptions based on contexts
	Hong	Michika	
Estimated Prevalence of GAM (%)	7.1	7.1	*As per the Upper-Confidence interval estimate of the 13th Round of NE-NFSS of June-July, 2023; [4.6(2.9-7.1, 95%CI)} of the Northern Adamawa Domain which includes Hong and Michika. Which also coincides with the GAM Point estimate for Adamawa in the NNHS-2018 [7.1 (4.8-10.4, 95% CI)].*
± Desired precision (%)	3.0	*3.0*	*Based on the recommendation of SMART survey guideline for precisions of prevalence <10%, 10-15%, 15-20% and above 20%.*
Design Effects for WHZ-score.	1.15	*1.15*	*Based on the 13th Round of NE-NFSS of June-July, 2023 observed DIFF for Northern Adamawa Domain which includes Hong and Michika.*
% Children Under-5	17.5	17.5	*Based on the Estimate from NE-NFSS Round 13 of June-July, 2023 for Northern Adamawa Domain which includes Hong and Michika and rounded up based on the contextual information of the survey area.*
Average HH Size	5.7	*5.7*	*Estimate from NE-NFSS Round 13, June-July, 2023.*
% Non-response Households	5.0	*5.0*	*Anticipated non-response based on contextual information conducting surveys in BAY states and this may adequately account for the Households refusal and exclusion due to flood experience.*
Households to be included	**372**	**372**	*Minimum sample size of Households as determined using SMART + and corroborated by ENA for SMART software.*
Children to be included	**352**	**352**	*Minimum sample size for children aged 0-59 months in the Households that will be surveyed as determined using SMART+ and corroborated by ENA for SMART software 6-59 months HH sample size (i.e., 413 multiplied by 0.9) [10].*

Outlier values were excluded from the data, with the log of exclusion being kept on the ENA file. The ages of respondents were entered in months for children (0-59), while the ages of adult respondents were entered in years. However, all necessary precautions were taken to protect the privacy of respondents.

2.7 Ethical Consideration

Several measures were taken to protect confidentiality, obtain informed consent, and minimize potential adverse consequences for participants. Confidentiality was clearly explained, and permission was obtained from interviewees to enter their documented responses into the survey database. All household Interviews were conducted in an open space to ensure confidentiality and avoid overcrowding; direct oral interviews with children were avoided at all costs due to concerns about child consent. Ethical approval authorizing this survey for were obtained.

3.0 Results and Discussion

3.1 Gaussian Distribution of Age and Sex of Sample for Hong and Michika Children

All the prevalence rates for the two locations as considered in this survey were based on the exclusion of z-scores from observed mean SMART flags: Weight-for-Height Z-score (WHZ) -3 to 3; Height-for-Age Z-score (HAZ) -3 to 3; and Weight-for-Age Z-score (WAZ) -3 to 3. However, Tables 2 and 3 shows the summary statistics of all the children (0-59) months that were enumerated, the sex distributions are all even, as corroborated in Figs. 1 and 2, where the sex curves mimics the normal curve, with an overall sex ratio of 0.7 for Hong as against the 0.9 in Michika, an indication of adequacy in sex ratio for Michika.

Table 2: Distribution of Age and Sex of Hong Children (0-59 months)

	Boys		Girls		Total		Ratio
AGE (mo)	**no.**	**%**	**no.**	**%**	**no.**	**%**	**Boy:girl**
0-5	2	22.2	7	77.8	9	2.3	0.3
6-23	57	47.8	62	52.2	119	30.4	0.9
24-35	42	57.5	31	42.5	73	18.6	1.4
36-47	47	51.6	44	48.4	91	23.2	1.1
48-59	41	41.0	59	59.0	100	25.5	0.7
Total	**189**	**48.2**	**203**	**51.8**	**392**	**100**	**0.7**

***Overall sex ratio :0.7 (boys and girls equally represented)**

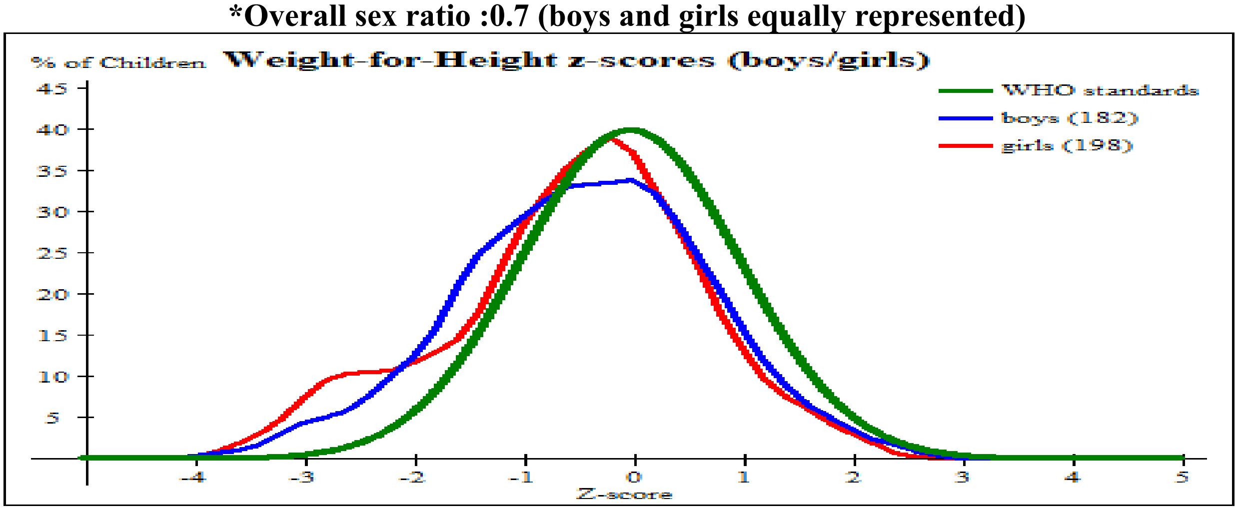

Fig. 1: Sex distribution Curve for Hong children (WFH)

Table 3: Distribution of Age and Sex of Michika Children (6-59 months)

	Boys		Girls		Total		Ratio
AGE (mo)	**no.**	**%**	**no.**	**%**	**no.**	**%**	**Boy:girl**
0-5	13	48.1	14	51.9	27	7.5	0.9
6-23	48	46.6	55	53.4	103	28.6	0.8
24-35	29	47.5	32	52.5	61	16.9	0.9
36-47	39	52.7	35	47.3	74	20.6	1.1
48-59	43	45.3	52	54.7	95	26.4	0.8
Total	**172**	**47.8**	**188**	**52.2**	**360**	**100**	**0.9**

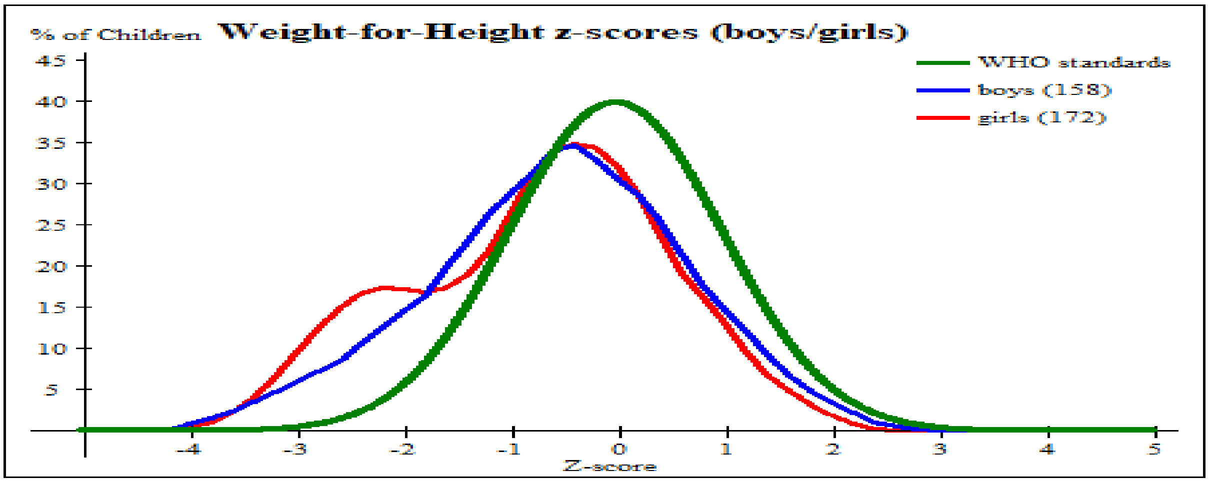

Fig. 2: Sex distribution Curve for Michika children (WFH)

The surveyed sample of children (6-59 months) had z-scores not available for 3 children in Hong and 3 in Michika with a statistical evaluation of age and sex ratios for boys and girls placed at 0.7 and 0.9 for Hong and Michika respectively. Indicating that the distribution, as dis-aggregated by age and sex has an overall sex ratio (male/female) p-value = 0.761 and 0.826 for Hong and Michika, respectively; indicating a sample with equal representation of boys and girls. As corroborated from Tables 2-3 and Figs. 1-2, the age/sex dis-aggregation showed that the normal distribution curve of the WFH z-score (in red and blue) mimics the WHO standards normal curve (in green), with a mean of -0.50 and a standard deviation of curve 1.11 for Hong children and a mean of -0.67 and a standard deviation of curve 1.17 for Michika children, indicating a noticeable skewness in sex ratio for girls in the two locations especially in Michika.

3.2 Gaussian Districution of underweight based on Weight-for-Age Z-scores by sex (0-59)

As presented in Figs. 3-4 below, the prevalence of underweight as per Weight-for-Age Z-score (WAZ) among children (6-59 months) in Hong is currently 24.2% (19.5 - 29.6 95% C.I.) while that of Michika is currently 26.1 % (20.2 - 32.9 95% C.I.). However, according to WHO severity thresholds (<10 low, 10-<20 medium, 20-<30 high and ≥30 Very high) the prevalence of severe underweight is presently categorized as "Low" in Hong with 6.9% (4.7 - 10.0 95% C.I.), while that of Michika is also "Low" with 6.4% (3.4 - 11.5 95% C.I.).

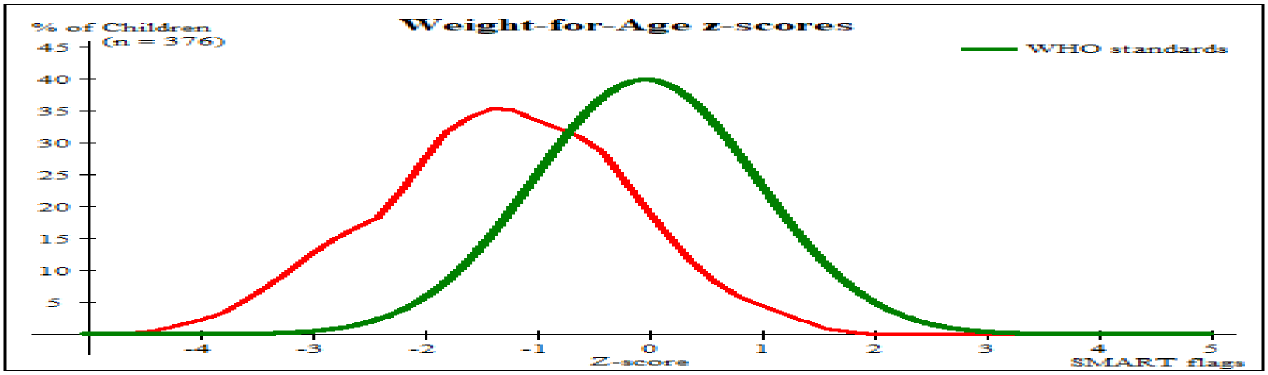

Fig. 3: Gaussian distribution Curve for Hong children (WFA) z-score

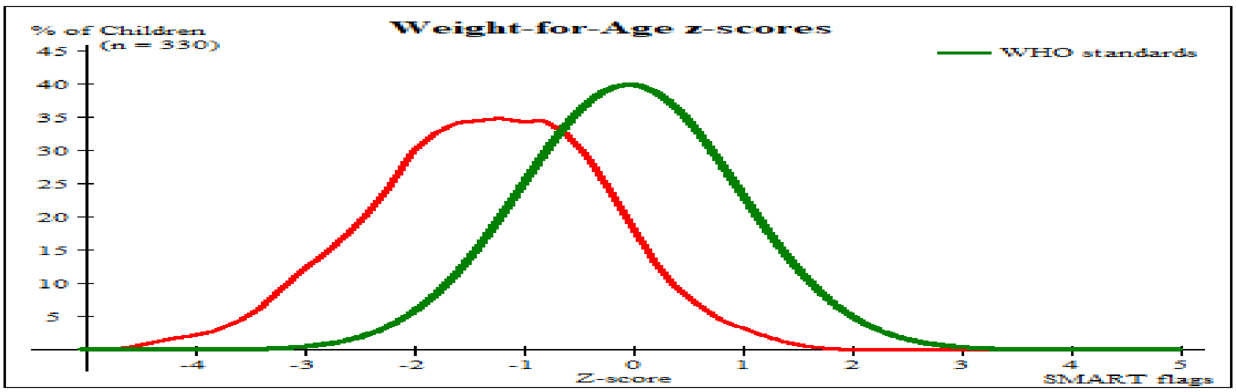

Fig. 4: Gaussian distribution Curve for Michika children (WFA) Z-score

The Weight-for-Age Z-score (WAZ) distribution curves (in red) as compared to the WHO 2006 reference Weight-for-Age Z-score distribution curve (in green) as presented in Figs. 3-4 above demonstrates a downward shift to the left, suggesting a "low" under-weighted population in Hong and Michika in comparison with the normal population.

3.3 Gaussian Distribution of stunting based on Height-for-Age Z-scores and by Sex (6-59) for Hong and Michika.

The point prevalence of stunting based on Height-for-Age Z-score (HAZ) among children 6-59 months in Hong is currently **38.5%** and 32.3% in Michika, which indicates that stunting prevalence is higher in Hong than in Michika. Meanwhile, as shown in Table 4 below, due to the high SD observed for stunting in the two locations, the stunting prevalence was recalculated to give the above point prevalence estimates without their corresponding confidence intervals and verifiable information on moderate and severe stunting.

The Height-for-Age Z-score (HAZ) distribution curve (in red) as compared to the SMART flags reference Height-for-Age Z-score (HAZ) distribution curve (in green) as presented in Fig. 5 and 6 above demonstrates a shift to the left and a non-peakness (Kurtosis) of the normal curves in red, suggesting a stunted population when compared to the normal population

Further analysis suggests that linear severe growth retardation is among the group of children aged 54-59 months as shown in the sample by age section of the figures where n = 25 and 35 respectively for Hong and Michika in Figs. 7- 8.

The Height-for-Age Z-score (HAZ)

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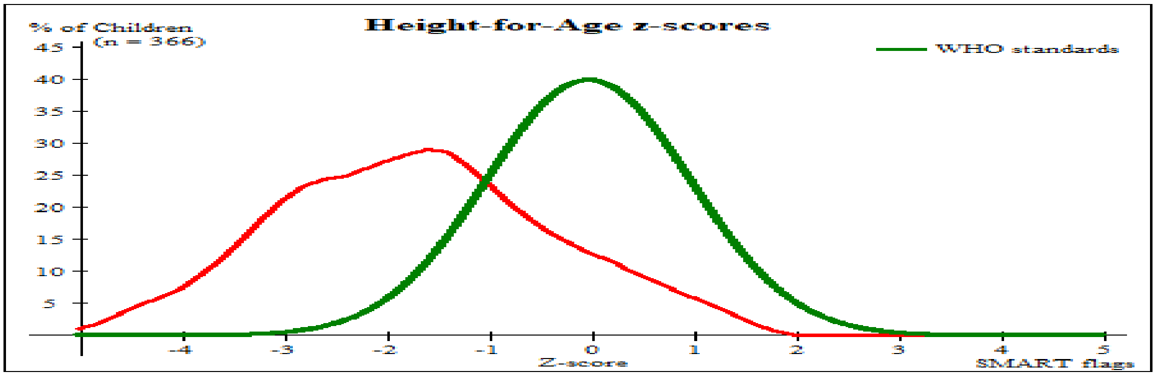

Fig. 5: Gaussian Distribution curve for Hong Children with (HFA) Z-score

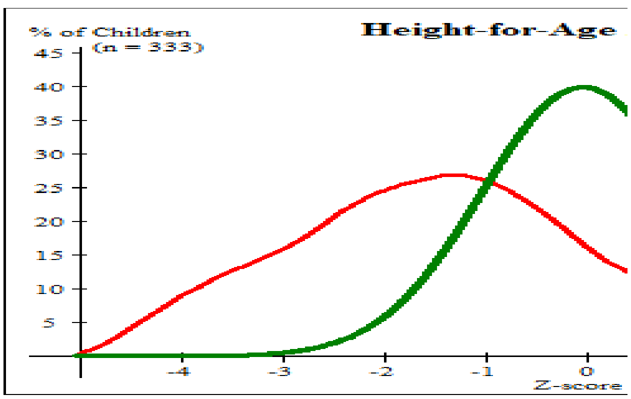

Fig. 6: Gaussian Distribution curve for Michika Children with (HFA) Z-score

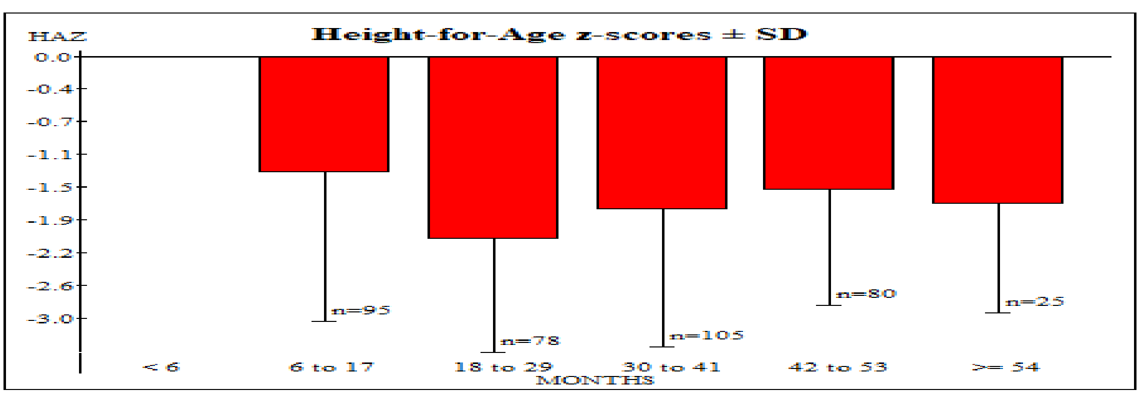

Fig. 7: Height-for-Age Z-score sample by Age Distribution for Hong

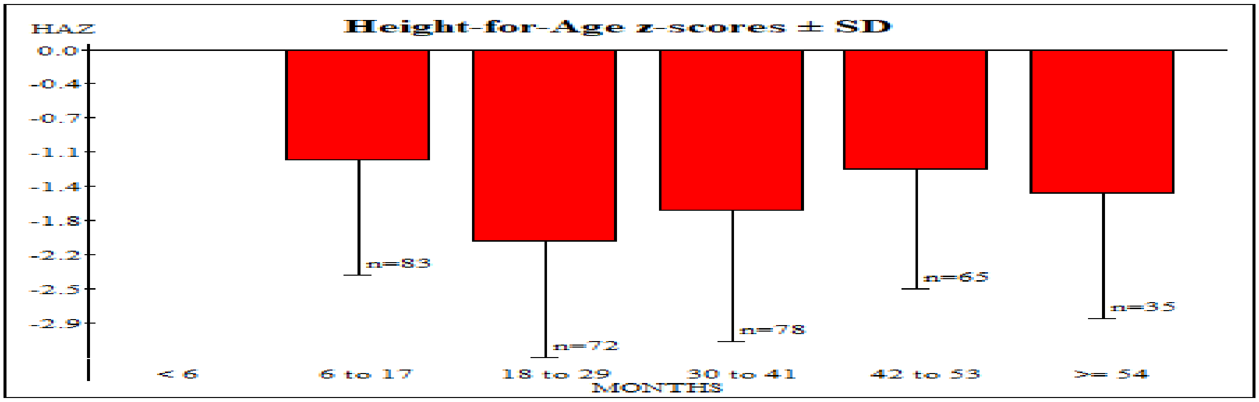

Fig. 8: Height-for-Age Z-score sample by Age Distribution for Michika

Table 4: Mean Z-scores, Design Effects and excluded subjects for Hong and Michika

Location/Indicator		**n**	**Mean Z-scores ± SD**	**Design Effect (z-score < -2)**	**z-scores not available***	**z-scores out of range**
Hong	Weight-for-Height	380	-0.50±1.11	1.30	3	0
	Weight-for-Age	376	-1.29±1.08	1.26	3	4
	Height-for-Age	366	-1.71±1.32	1.27	0	17
Michika	Weight-for-Height	330	-0.67±1.17	1.63	3	0
	Weight-for-Age	330	-1.33±1.04	1.64	3	0
	Height-for-Age	333	-1.54±1.35	2.03	0	0

*** contains for WHZ and WAZ the children with oedema**.

From Table 4 above, one can clearly see that the mean and standard deviation when indexed by WFH is in all of the two locations consistently smaller than the other two indices, i.e. WFA and HFA, hence, it is more efficient in estimating the prevalence rates among the three indicators compared here. For instance, -0.50±1.11 in Hong and -0.67±1.17 in Michika. However, the standard deviations for HFA in the two locations exceeded the required range of 0.8-1.2, hence; they were re-calculated with SD of 1.0 to give new point intervals of **38.5%** and **32.3%** stunting prevalence rates for Hong and Michika respectively.

4.0 Conclusion

This study assessed the Gaussian distribution of age and sex among children aged 0–59 months using data from SMART nutrition surveys conducted in Hong and Michika Local Government Areas of Adamawa State, Nigeria. The findings demonstrate that the sampled populations in both locations exhibited age and sex distributions that closely approximated the expected Gaussian pattern, indicating satisfactory sample representativeness and good overall survey quality. The observed sex ratios of 0.7 for Hong and 0.9 for Michika, together with non-significant p-values (0.761 and 0.826, respectively), confirm that boys and girls were adequately represented in both surveys.

The Gaussian distribution curves for Weight-for-Height (WHZ), Weight-for-Age (WAZ), and Height-for-Age (HAZ) provided valuable insights into the quality of the anthropometric data and the nutritional status of the study population. The WHZ distributions closely resembled the WHO reference curves, indicating acceptable data quality and reliable estimates of acute malnutrition. In contrast, the WAZ and HAZ curves were shifted to the left of the WHO reference distribution, reflecting the persistence of underweight and stunting among children in the two study areas. Hong showed a slightly greater deviation from the reference distribution than Michika, suggesting comparatively poorer nutritional outcomes.

Furthermore, the analysis demonstrated that the WHZ index exhibited smaller standard deviations than the WAZ and HAZ indices, indicating greater precision and reliability for estimating acute malnutrition prevalence. Although the HAZ distributions required recalculation because of elevated standard deviations, the adjusted estimates remained consistent with the observed burden of chronic malnutrition.

Overall, the findings confirm that Gaussian distribution analysis is a valuable quality assurance tool in SMART nutrition surveys, providing confidence in the representativeness of survey samples and the validity of anthropometric estimates. The study also highlights the continued burden of undernutrition, particularly stunting, among under-five children in Hong and Michika, underscoring the need for sustained nutrition interventions, routine surveillance, and evidence-based public health programmes to improve child nutritional outcomes in the study area.

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Declarations

Ethical Approval and Consent to Participate

The nutrition survey from which the data for this study were obtained was conducted in accordance with the Standardized Monitoring and Assessment of Relief and Transitions (SMART) methodology and relevant national guidelines for nutrition surveys. Ethical approval for the survey was obtained from the appropriate authorities before data collection. Written or verbal informed consent, as appropriate, was obtained from all participating caregivers and adult respondents prior to their inclusion in the survey. All data used in this study were anonymized, and confidentiality was maintained throughout the analysis.

Consent for Publication

Not applicable.

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Data Availability Statement
Data can be provided upon request

Authors' Contributions
Anthony Ekpo conceived and designed the study, performed the statistical analyses, interpreted the results, and drafted the manuscript. Blessing Iveren Yaweh contributed to data interpretation, reviewed the statistical analyses, critically revised the manuscript for important intellectual content, and approved the final version of the manuscript. Both authors read and approved the final manuscript.

Competing Interests
The authors declare that they have no competing interests or conflicts of interest regarding the publication of this manuscript.