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Exploring Malnutrition Risk among Infants under Five Years in Guéra Province, Chad: A Cross-Sectional Study

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Abstract

Background: Malnutrition, a serious public health concern, is influenced by various factors. **Objective:** The study aims to explore malnutrition issues among infants under five years old in Guéra Province. **Methods:** The study used a cross-sectional design and a two-stage cluster sampling method to select participants. The study population was infants aged between 0 - 24 months. Data collection was done between June 2023 and September 2024; it included anthropometric measurements, blood analyses, and interviews. Anthropometric parameters were calculated using ENA for SMART software. Statistical analyses were performed by R Studio to investigate associations between different characteristics, using logistic regression models to identify risk factors. A p-value less than 0.05 was considered significant. **Results:** The study included 377 infants in eight villages in Guéra Province, Chad. The sample was predominantly girls (55.3%), with a median age of 16 months. Most infants (94%) were mixed-fed, and only 6% were exclusively breastfed. We found that 7.3% of children were globally malnourished, with higher rates in boys 9.6%. A significant disparity existed between boys and girls in global acute malnutrition (GAM) rates, with boys having a higher prevalence of 17.9%. A substantial proportion of Infants were underweight, with males 27.4%. Stunting was prevalent of 20.1%. Several factors were associated with malnutrition, including gender, feeding practices, infectious diseases, and socioeconomic factors. Diarrhea, malaria, limited access to drinking water, and early diet diversification were significantly associated with malnutrition. **Conclusion:** Targeted interventions are necessary to address these issues and improve the nutritional status of children in the Guéra province.

Keywords

Malnutrition, Undernutrition, Overnutrition, Stunting, Wasting, Infant

1. Introduction

Malnutrition, a state of nutritional imbalance, can be categorized into two primary forms: undernutrition and overnutrition. Undernutrition, characterized by inadequate consumption of calories, protein, or micronutrients, results in a deficit of essential nutrients. This deficiency can manifest in various forms, including wasting, stunting, and underweight. Conversely, overnutrition, arising from excessive consumption of certain nutrients, often leads to obesity, a condition characterized by an abnormal accumulation of body fat [1]-[3].

Malnutrition is a pervasive health issue that afflicts a significant portion of the global population. This nutritional imbalance can lead to a spectrum of health problems [3]-[5]. Malnutrition can have severe consequences for both individuals and communities. Children who are malnourished may experience stunted growth, meaning they are shorter than what is expected for their age [6]. This is often attributed to a deficiency in essential nutrients, particularly protein and micronutrients, during critical periods of development. Another manifestation of malnutrition is wasting, where children appear too thin for their height [7]. This indicates a rapid loss of weight, often due to acute food deprivation or underlying illnesses, and can severely compromise a child's health and development. Malnutrition can negatively impact brain development, leading to cognitive impairments and learning difficulties. This is because the brain requires a steady supply of nutrients, including essential fatty acids and amino acids, for optimal growth and function [8].

Additionally, malnourished individual's immune system is often compromised, making them more susceptible to infections and diseases. This is due to reduced production of antibodies and other immune cells, as well as impaired nutrient absorption, which is necessary for a healthy immune response [7] [9]-[11]. Conversely, overnutrition, resulting from excessive nutrient intake, often leads to obesity [6]. Obesity is a complex condition associated with a range of health risks, including cardiovascular disease, type 2 diabetes, and certain types of cancer. The excess weight can put a strain on the body's organs and systems, increasing the likelihood of developing chronic illnesses [10] [12]. Malnutrition can also reduce an individual's ability to work and contribute to the economy. This is because chronic malnutrition can lead to fatigue, weakness, and reduced physical and mental capacity [12].

Malnutrition can be caused by a variety of factors, including poverty, food insecurity, lack of education, illness, conflict, and environmental problems [2] [13] [14]. Poverty can lead to malnutrition because people cannot afford to buy healthy food. Food insecurity can occur when people do not have enough food to eat, which can be caused by factors such as poverty, conflict, and natural disasters [15]-[17]. Lack of education can also contribute to malnutrition because people may not know how to cook healthy meals [15]. Illnesses such as HIV/AIDS and malaria can make it difficult for the body to use nutrients, leading to malnutrition. Conflicts and disasters can disrupt food production and distribution, leading to food insecurity and malnutrition. Environmental problems such as climate change and natural disasters can also affect food availability, leading to malnutrition [18]-[23].

In 2022, the global prevalence of undernourishment was 9.2%, or roughly 828 million people. This alarming statistic reveals a significant portion of the world's population lacks consistent access to sufficient food for their nutritional needs. Sub-Saharan Africa, with a staggering 22.5% prevalence, faces the most severe undernourishment crisis among all global regions. Children in this region are disproportionately affected by malnutrition, highlighting the urgent need for targeted interventions to address this critical issue [3] [14]. Malnutrition in Sub-Saharan Africa persists as a critical public health burden, posing a significant threat to community well-being and development. Limited access to essential resources, including food, healthcare, and clean water, exacerbates the prevalence of malnutrition and its associated health consequences [24]-[28]. EDS, MICS, and SMART surveys reveal a deep-rooted nutritional crisis in Chad, particularly in the Sahel region. In 2013, Guéra province recorded alarming rates of acute malnutrition (11.6%), chronic malnutrition (26.7%), and stunting (21.5%) among children under five. These figures are linked to a multitude of factors, including poverty, food insecurity, and inadequate infant feeding practices. Indeed, in 2010, only 3.4% of infants were exclusively breastfed, and 19.9% were born with low birth weight. This situation jeopardizes the health and development of an entire generation [29]. The aims of this study were to assess the prevalence of malnutrition in infants in Guéra Province, Chad, and identify the factors associated with malnutrition risk among infants in the study area.

2. Materials and Methods

2.1. Study Areas

Chad is one of the vast territories located in the heart of the African continent, between the 8th and 24th degrees of North latitude and the 13th and 24th degrees of East longitude (**Figure 1**). It covers an area of 1,284,000 km^2. Completely landlocked, it is surrounded by Libya to the North, the Central African Republic to the South, North Sudan to the East, and Cameroon, Niger, and Nigeria to the West.

From the immense desert of the Sahara in the north to the wetlands in the south, passing through savannas and mountainous massifs, the country offers a range of landscapes that are contrasting and fascinating. At the heart of this geographical mosaic lies the province of Guéra [29]-[31]. Bordered by the provinces of Batha, Salamat, Ouaddaï, Moyen-Chari, Chari-Baguirmi, and Hadjer-Lamis, the province of Guéra occupies a strategic geographical position. Its relief, marked by an alternation of plains, plateaus, and mountainous massifs, culminates at Mount Guéra [30]. The challenges facing the Guéra province are closely interconnected. Climate hazards exacerbate ecosystem degradation by amplifying the pressure on natural resources. This degradation, coupled with limited access to basic services, contributes to food insecurity and poverty. It is a vicious cycle that hinders the sustainable development of the region [32].

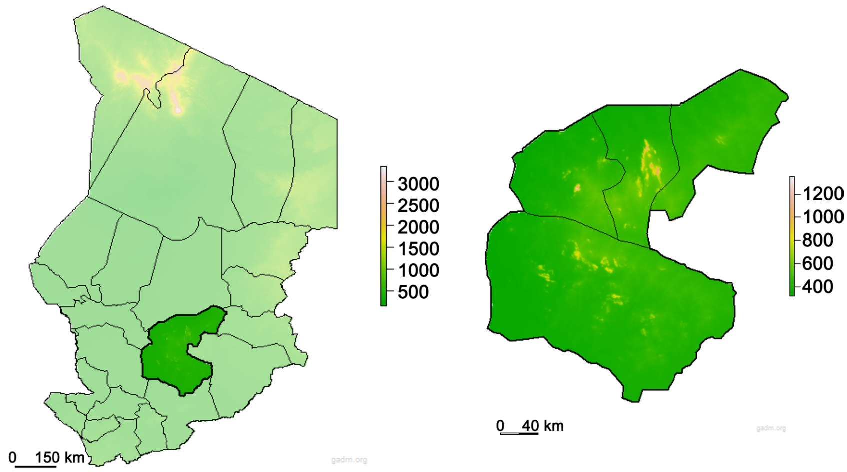

Figure 1. A map of the Republic of Chad, Guéra Province, and sub-divisions [33].

2.2. Study Design and Period

The study conducted was cross-sectional. Data collection took place between June 2023 and September 2024.

2.3. Study Population

The study population was comprised of infants aged 0 - 24 months who resided in the province of Guéra. Only infants without pre-existing chronic illnesses or immunodeficiency were enrolled.

2.4. Sampling

1) ***Sample size determination***

The sample size was calculated using the following Cochrane formula:

$$n = \frac{Z_\alpha^2 P(1-P)}{d^2} \quad [34],$$

where: n = the required minimum sample size; Z_α = the standard normal deviate, corresponding to the desired confidence level (1.96 for a 95% confidence interval);

P = the estimated prevalence of chronic malnutrition in Guéra (26.7% in this case) [29]; d = the desired margin of error or precision (0.05). Based on the given values, the calculation yields a minimum sample size of 301 participants. In order to address the possibility of non-response bias, which might lead to a reduction in the effective sample size, the sample size was expanded by roughly 10% to 331.

2) ***Sampling method and technique***

To ensure the representativeness of the sample in a geographically dispersed population, a two-stage cluster sampling design was implemented. This survey strategy, selected for its cost-effectiveness, was inspired by the 2022 SMART (Standardized Monitoring and Assessment of Relief and Transition) nutritional survey in Chad, from which we adopted the main methodological elements [29].

A two-stage sampling design was employed to select households in Guéra Province. In the first stage, a simple random sample without replacement was used to select 8 villages from total villages. To ensure representativeness, proportional-to-size sampling was implemented, with the probability of selecting a village proportional to its size. A sampling frame was utilized to facilitate this selection. In the second stage, a systematic random sampling approach was adopted within each selected village. A random starting point was chosen, and one household was selected for every P household, where P is the sampling interval. This interval was calculated by dividing the total number of households enumerated (N) in the village by the number of households to survey (n), resulting in a sampling ratio $P = N/n$.

Prior to data collection, village authorities were approached to secure their consent and cooperation for the study. A preliminary field assessment was conducted to enumerate households and establish a comprehensive sampling frame. A simple random sampling method was then employed to select households for the survey, ensuring the representativeness of the sample.

To ensure comprehensive and consistent data collection, a systematic numbering system was implemented for the observation units. Starting from the northeasternmost point of each village and progressing towards the southwest, each compound was assigned a unique number preceded by the letter "C". Within each compound, households were numbered sequentially, starting from "1". This numbering was clearly marked on the main entrance doors.

3) ***Definitions***

Compound: A compound refers to a residential unit, whether it consists of a single house or a group of buildings. It may or may not be enclosed and may accommodate one or more households [29].

Household: A household is defined as a group of people living together in the same dwelling, sharing meals, and recognizing a common authority (the head of household). Household members may be related by blood, marriage, or simply by the fact of sharing a living space and common resources [29].

Compound Head: The compound head is the recognized authority figure within the compound. This may be the owner, an elder, or any other individual vested with this role by the compound members [29].

2.5. Data Collection

To ensure a harmonized and efficient data collection process, we developed an electronic questionnaire specifically tailored to the context of Guéra Province. This questionnaire was deployed on digital tablets equipped with the KoboCollect application. Enumerators were thus able to enter data directly into the field, allowing for the real-time transmission of collected information to a centralized storage platform.

2.6. Measurement and Diagnosis of Anaemia, Malaria and Child Malnutrition

1) ***Anaemia***

A 2 mL venous blood sample was collected from each fasting participant and immediately analysed using a HemoCue 301 automated haematology analyser. Haemoglobin measurement, an essential protein for oxygen transport, was used to assess the participants' anaemic status. Results were interpreted in reference to the World Health Organization reference values, which define a haemoglobin threshold below 11 g/dL as indicative of anaemia. [35]

2) ***Malaria***

To assess history of malaria of children, mothers were interviewed about their child's history of malaria since birth. To confirm this self-reported information, we systematically requested the presentation of health records or medical consultation slips. Only cases for which a medical document corroborated the malaria diagnosis were retained as children who had experienced malaria.

3) ***Anthropometric assessment and nutritional status evaluation***

To comprehensively evaluate the nutritional status of the children, an anthropometric assessment, was conducted. Children were weighed naked on a calibrated SECA dual-reading scale with a precision of 0.1 kg. Scales were checked and calibrated after each group of 10 children. Mid-Upper Arm Circumference (MUAC) was measured using a graduated tape measure in millimeters. The measurement was taken on the left arm, midway between the acromion (tip of the shoulder) and the olecranon (elbow), to the nearest millimeter. MUAC is an indirect indicator of muscle mass and fat stores. Height was measured using a graduated wooden stadiometer. Children taller than 87 cm were measured standing upright, while those shorter were measured lying down. Height was measured to the nearest 0.1 cm.

Weight-for-Age (WFA), Height-for-Age (HFA), and Weight-for-Height (WFH) were calculated. WFA reflects overall growth and is used to identify chronic underweight. HFA is a measure of linear growth and is used to identify stunting. WFH is a sensitive indicator of acute malnutrition, often associated with wasting [36]-[38].

We used Z-scores derived from WFH, HFA, and MUAC to identify respectively children suffering from acute malnutrition, chronic malnutrition or both acute and chronic malnutrition. These acute malnutrition and chronic malnutrition were classified as Mild Malnutrition, Moderate Malnutrition, and Severe Malnutrition. The definition of malnutrition was based on WHO standards 2006 [39]-[42].

2.7. Data Preparation and Statistical Analysis

To prepare the data for statistical analysis, a Microsoft Excel spreadsheet was used for data cleaning and organization. This crucial step allowed for the identification and correction of any data entry errors or inconsistencies. Descriptive statistics, including normality tests, were employed to characterize the data and select appropriate analytical methods. Anthropometric parameters WFH, HFA, WFA, and Z-scores for these parameters were subsequently determined using Software for Emergency Nutrition Assessment (ENA) for SMART. Other statistical analyses were conducted using the open-source software R Studio (version 4.4.1) to investigate associations between different characteristics within our population, and suitable statistical tests were applied. To delve deeper into the analysis and assess the impact of multiple factors on the risk of malnutrition, logistic regression models were implemented. These statistical models enabled the identification of the most significant risk factors while accounting for the confounding effects of other variables. A p-value less than 0.05 was considered statistically significant.

2.8. Ethical Considerations

To ensure the scientific rigor and ethical compliance of the study, a strict protocol was implemented and approved by local authorities. Informed consent or assent was obtained from parents or guardians of all participating infants after receiving a clear and comprehensive explanation of the study's objectives, the nature of the procedures involved (including anthropometric measurements), and the assurances of confidentiality. The participants were allowed to stop their participation at any time and period of the study at their convenience without any negative consequence regarding their decision to stop. Researchers were careful to address all their questions. This approach allowed for the collection of reliable data, essential for an accurate assessment of the children's nutritional status. Furthermore, it ensured the appropriate management of identified cases of malnutrition in accordance with the recommendations of the ethical comity of the Chad Ministry of Public Health (reference N˚6010/PT/PM/MSPP/SE/SG/DGSP/DANA/2023).

3. Results

3.1. Demographic Characteristics of Study Participants

The study was conducted in eight villages within Guéra Province, Chad, with a total of 378 infants enrolled. The specific number of households surveyed in each village is detailed in **Figure 2**. The sample consisted of 209 females (55.3%) and 168 males (44.7%) (**Figure 3**) with a median age of 16 months (range: 1 - 24 months). The mean age was 15.31 months (SD = 5.17), with a median weight of 8.00 kg (range: 4.00 - 11.00 kg) and a mean weight of 7.59 kg (SD = 1.30). The median height was 71.00 cm (range: 6.00 - 92.00 cm), and the mean height was

69.71 cm (SD = 8.41).

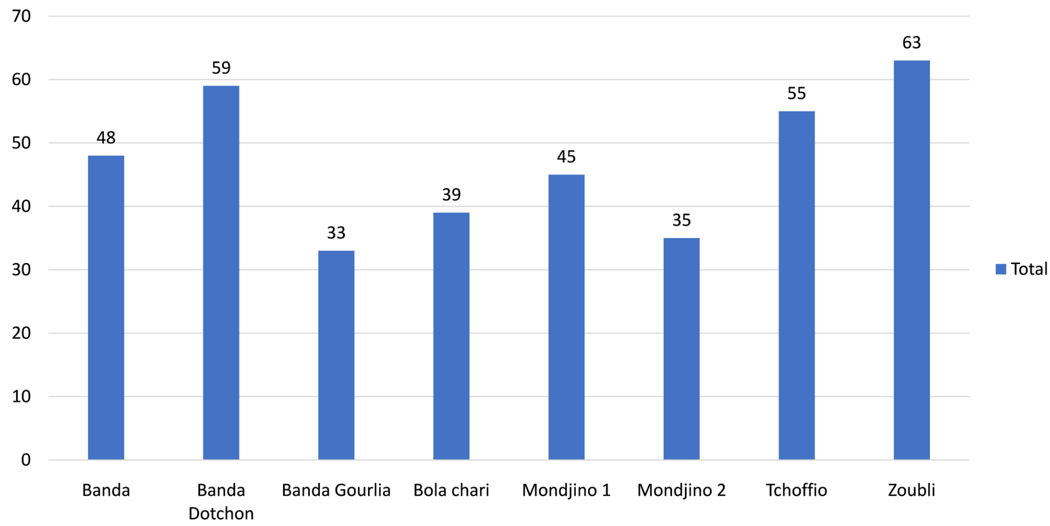

Figure 2. Number of households surveyed in each village.

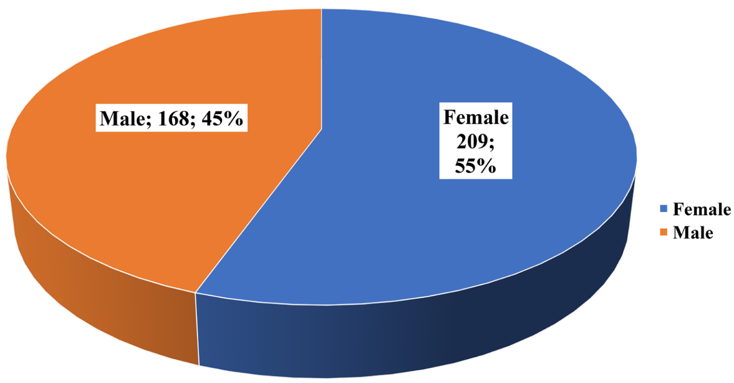

Figure 3. Repartition of infants by sex.

The majority of infants (94%) received mixed feeding, with only 6% (n = 21) being exclusively breastfed (EBF). All exclusively breastfed infants were aged 1 - 6 months. (Figure 4)

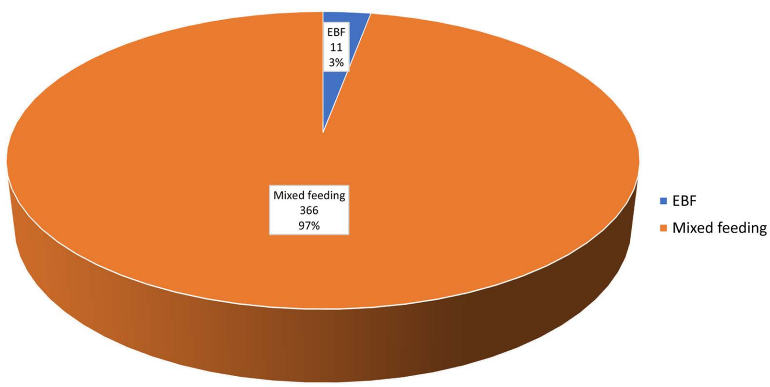

Figure 4. Repartition of infants by nutrition.

A slight gender imbalance was observed, with a higher proportion of girls (55.4%) compared to boys (44.6%). The sex ratio was 0.8. Gender differences were more pronounced in younger age groups, with a predominance of girls in the 0 - 11-month age range. However, gender distribution became more balanced in the older age groups (12 - 24 months). (**Table 1**)

Table 1. Distribution of age and sex.

	Boys	Girls	Total	Ratio
AGE (mo)	**no. (%)**	**no. (%)**	**no. (%)**	**Boy:Girl**
0 - 5	0 (0.0)	3 (100.0)	3 (0.8)	0.0
6 - 11	28 (36.4)	49 (63.6)	77 (20.4)	0.6
12 - 17	93 (49.7)	94 (50.3)	187 (49.6)	1.0
18 - 24	47 (42.7)	63 (57.3)	110 (29.2)	0.7
Total	168 (44.6)	209 (55.4)	377 (100.0)	0.8

3.2. Prevalence of Malnutrition in Population

1) ***Based on sex***

Across the study population, 7.3% of children were classified as globally malnourished. When examining gender differences, boys had a slightly higher prevalence (9.6%) compared to girls (5.5%). However, the overlapping confidence intervals indicate that this observed difference might not be statistically significant. This suggests that there is no clear evidence to support a significant gender-based disparity in global malnutrition rates. A higher proportion of children (6.5%) exhibited moderate malnutrition. Similar to global malnutrition, boys had a slightly higher rate (8.3%) compared to girls (5.0%). However, the lack of statistical significance in this difference suggests that there is no strong evidence to support a gender-based disparity in moderate malnutrition rates. Severe malnutrition was relatively rare, with only 0.8% of children affected. Boys had a slightly higher rate (1.3%) compared to girls (0.5%), but this difference was not statistically significant. (**Table 2**)

A comprehensive analysis of global acute malnutrition (GAM) within the studied population revealed an overall prevalence of 13.0%. When examining the data by gender, a statistically significant disparity emerged, with boys exhibiting a considerably higher rate of GAM at 17.9% compared to girls at 9.1%. In contrast, the prevalence of severe acute malnutrition (SAM) was observed to be lower at 1.6%. Although boys demonstrated a slightly elevated rate of SAM (2.4%) compared to girls (1.0%), however, this difference was not statistically significant. (**Table 2**)

Our analysis indicates a general prevalence of underweight within the population, affecting 20.3% of individuals. When stratified by gender, a statistically significant disparity emerges, with males exhibiting a considerably higher rate of underweight (27.4%) than females (14.5%). Regarding the severity of underweight, a substantial proportion of children (15.7%) were categorized as moderately underweight. Once again, males demonstrated a slightly elevated rate (19.6%) compared to females (12.6%). The prevalence of severe underweight was relatively low, affecting 4.5% of the child population. Notably, males exhibited a markedly higher rate of severe underweight (7.7%) than females (1.9%). (Table 2)

Table 2. Prevalence of malnutrition in studied population based on sex.

	Total (no.) % (95% C.I.)	Boys (no.) % (95% C.I.)	Girls (no.) % (95% C.I.)
Acute malnutrition based on WHZ (and/or oedema)	**n = 355**	**n = 156**	**n = 199**
GM (<−2 z-score and/or oedema)	(26) 7.3 (5.0 - 10.5)	(15) 9.6 (5.9 - 15.3)	(11) 5.5 (3.1 - 9.6)
MM (<−2 z-score and ≥−3 z-score. no oedema)	(23) 6.5 (4.4 - 9.5)	(13) 8.3 (4.9 - 13.7)	(10) 5.0 (2.8 - 9.0)
SM (<−3 z-score and/or oedema)	(3) 0.8 (0.3 - 2.5)	(2) 1.3 (0.4 - 4.6)	(1) 0.5 (0.1 - 2.8)
Acute malnutrition based on MUAC cut off's (and/or oedema)	**n = 374**	**n = 168**	**n = 206**
GM (<125 mm and/or oedema)	(32) 8.6 (6.1 - 11.8)	(20) 11.9 (7.8 - 17.7)	(12) 5.8 (3.4 - 9.9)
MM (<125 mm and ≥115 mm. no oedema)	(27) 7.2 (5.0 - 10.3)	(17) 10.1 (6.4 - 15.6)	(10) 4.9 (2.7 - 8.7)
SM (<115 mm and/or oedema)	(5) 1.3 (0.6 - 3.1)	(3) 1.8 (0.6 - 5.1)	(2) 1.0 (0.3 - 3.5)
Combined GAM and SAM based on WHZ and MUAC cut off's (and/or oedema)	**n = 377**	**n = 168**	**n = 209**
Combined GAM (WHZ < −2 and/or MUAC < 125 mm and/or oedema)	(49) 13.0 (10.1 - 16.9)	(30) 17.9 (12.8 - 24.3)	(19) 9.1 (6.0 - 14.0)
Combined SAM (WHZ < −3 and/or MUAC < 115 mm and/or oedema)	(6) 1.6 (0.7 - 3.5)	(4) 2.4 (0.9 - 6.0)	(2) 1.0 (0.3 - 3.5)
Underweight based on WAZ	**n = 375**	**n = 168**	**n = 207**
Global underweight (<−2 z-score)	(76) 20.3 (16.5 - 24.6)	(46) 27.4 (21.2 - 34.6)	(30) 14.5 (10.3 - 19.9)
Moderate underweight (<−2 z-score and ≥−3 z-score)	(59) 15.7 (12.4 - 19.8)	(33) 19.6 (14.3 - 26.3)	(26) 12.6 (8.7 - 17.8)
Severe underweight (<−3 z-score)	(17) 4.5 (2.8 - 7.1)	(13) 7.7 (4.6 - 12.8)	(4) 1.9 (0.8 - 4.9)
Stunting based on HAZ	**n = 319**	**n = 135**	**n = 184**
Global stunting (<−2 z-score)	(64) 20.1 (16.0 - 24.8)	(33) 24.4 (18.0 - 32.3)	(31) 16.8 (12.1 - 22.9)
Moderate stunting (<−2 z-score and ≥−3 z-score)	(24) 7.5 (5.1 - 11.0)	(11) 8.1 (4.6 - 14.0)	(13) 7.1 (4.2 - 11.7)
Severe stunting (<−3 z-score)	(40) 12.5 (9.3 - 16.6)	(22) 16.3 (11.0 - 23.4)	(18) 9.8 (6.3 - 14.9)
Overweight based on WHZ (no oedema)	**n = 355**	**n = 156**	**n = 199**
Overweight (WHZ > 2)	(15) 4.2 (2.6 - 6.9)	(8) 5.1 (2.6 - 9.8)	(7) 3.5 (1.7 - 7.1)
Severe overweight (WHZ > 3)	(0) 0.0 (0.0 - 1.1)	(0) 0.0 (0.0 - 2.4)	(0) 0.0 (0.0 - 1.9)

GM: Global Malnutrition; MM: Moderate Malnutrition; SM: Severe Malnutrition; GAM: Global Acute Malnutrition; SAM: Severe Acute Malnutrition; HAZ: Height-for-Age Z-Scores; WAZ: Weight-for-Age Z-Scores; WHZ: Weight-for-Height Z-Scores; C.I.: Confidence Interval; The prevalence of oedema is 0.0%.

The study revealed a 20.1% prevalence of stunting among the population. A slight gender disparity was observed, with boys exhibiting a higher rate of stunting (24.4%) than girls (16.8%). Regarding the severity of stunting, 7.5% of the children were classified as moderately stunted, with no significant gender differences. However, a higher prevalence of severe stunting was found in 12.5% of the children, with boys showing a slightly higher rate (16.3%) compared to girls (9.8%). (Table 2)

The prevalence of overweight was significantly lower at 4.2% of the population. Boys exhibited a marginally higher rate of overweight (5.1%) than girls (3.5%), but this difference was not statistically significant. Notably, no child in the study was classified as severely overweight. (Table 2)

2) ***Based on age***

Table 3. Prevalence of malnutrition in the studied population based on age.

	Age (mo)	0 - 5	6 - 11	12 - 17	18 - 24	Total
Acute malnutrition based on WHZ and/or oedema	**Total no.**	3	74	179	99	355
Severe wasting (<−3 z-score)	**no. (%)**	0 (0.0)	0 (0.0)	3 (1.7)	0 (0.0)	3 (0.8)
Moderate wasting (≥−3 and <−2 z-score)	**no. (%)**	0 (0.0)	3 (4.1)	14 (7.8)	6 (6.1)	23 (6.5)
Normal (≥−2 z score)	**no. (%)**	3 (100.0)	71 (95.9)	162 (90.5)	93 (93.9)	329 (92.7)
Oedema	**no. (%)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Acute malnutrition based on MUAC cut off's and/or oedema	**Total no.**		77	187	110	374
Severe wasting (<115 mm)	**no. (%)**		0 (0.0)	5 (2.7)	0 (0.0)	5 (1.3)
Moderate wasting (≥115 mm and <125 mm)	**no. (%)**		1 (1.3)	13 (7.0)	13 (11.8)	27 (7.2)
Normal (≥125 mm)	**no. (%)**		76 (98.7)	169 (90.4)	97 (88.2)	342 (91.4)
Oedema	**no. (%)**		0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Underweight based on WAZ	**Total no.**	3	77	187	108	375
Severe underweight (<−3 z-score)	**no. (%)**	0 (0.0)	1 (1.3)	10 (5.3)	6 (5.6)	17 (4.5)
Moderate underweight (≥−3 and <−2 Z-score)	**no. (%)**	0 (0.0)	7 (9.1)	29 (15.5)	23 (21.3)	59 (15.7)
Normal (≥−2 Z-score)	**no. (%)**	3 (100.0)	69 (89.6)	148 (79.1)	79 (73.1)	299 (79.7)
Oedema	**no. (%)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)
Stunting by age based on HAZ	**Total no.**	3	70	161	85	319
Severe stunting (<−3 Z-score)	**No. (%)**	0 (0.0)	3 (4.3)	19 (11.8)	18 (21.2)	40 (12.5)
Moderate stunting (≥−3 and <−2 Z-score)	**No. (%)**	0 (0.0)	1 (1.4)	16 (9.9)	7 (8.2)	24 (7.5)
Normal (≥−2 Z-score)	**No. (%)**	3 (100.0)	66 (94.3)	126 (78.3)	60 (70.6)	255 (79.9)
Overweight based on WHZ (no oedema)	**Total no.**	3	74	179	99	355
Overweight (WHZ > 2)	**No. (%)**	0 (0.0)	4 (5.4)	5 (2.8)	6 (6.1)	15 (4.2)
Severe Overweight (WHZ > 3)	**No. (%)**	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)

HAZ: Height-for-Age Z-Scores; WAZ: Weight-for-Age Z-Scores; WHZ: Weight-for-Height Z-Scores; *With SMART or WHO flags a missing MUAC/WHZ or not plausible WHZ value is considered as normal when the other value is available.

A comprehensive nutritional assessment of the children identified a low incidence of severe acute malnutrition (SAM). Only 0.8% of children were classified as severely wasted. However, a higher prevalence of moderate acute malnutrition (MAM) was observed, affecting 6.5% of the population. Age-specific analysis revealed a significant association between MAM and older age groups, with children aged 6 - 11 months, 12 - 17 months, and 18 - 24 months exhibiting notably higher rates of MAM compared to those aged 0 - 5 months (Table 3). Importantly, no cases of severe malnutrition with oedema were detected in any age group.

The study identified a minimal incidence of severe undernutrition, with only 4.5% of children meeting the diagnostic criteria. Conversely, a more substantial proportion, 15.7%, demonstrated moderate underweight. (Table 3)

A stratified analysis by age revealed a disproportionate burden of undernutrition in older age groups. The 18 - 24-month cohort exhibited the highest prevalence of both moderate (21.3%) and severe (5.6%) underweight. The 12 - 17-month group also demonstrated a notably high incidence of severe underweight (5.3%). Conversely, the 6 - 11-month group exhibited lower rates of both moderate (9.1%) and severe (1.3%) undernutrition. Importantly, no child in any age group displayed clinical evidence of oedema, a severe manifestation of malnutrition. (Table 3)

Stunting was pervasive across all age groups, with a particularly high prevalence in older children. The 12 - 17-month cohort exhibited the most severe stunting at 11.8%, followed by the 18 - 24-month group at 21.2%. Moderate stunting was also more prevalent in these older age groups, occurring in 9.9% and 8.2% of children, respectively. (Table 3)

Overweight was observed in all age groups except the youngest (0 - 5 months). The highest rate of overweight was identified in the 18 - 24-month cohort, reaching 6.1%. These findings indicate a rising risk of overweight with increasing age. However, no child in the study population exhibited severe overweight.

3.3. Univariate and Multivariate Regression

1) ***Univariate regression results on malnutrition***

Malnutrition is a significant issue affecting children, particularly those from lower socioeconomic backgrounds. Several factors contribute to malnutrition, including gender disparities, feeding practices, infectious diseases, and environmental conditions. Male children are generally less likely to be malnourished than female children. Children who rely solely on breast milk or are introduced to solid foods too early or too late are at higher risk. Infectious diseases like malaria, especially when undiagnosed, can exacerbate malnutrition. Anaemia, however, may offer some protection. Access to clean water and adequate living conditions are crucial for preventing malnutrition. Early and diverse introduction of complementary foods, along with proper hygiene practices, can reduce the risk. Higher child health expenditure and socioeconomic status are associated with lower malnutrition rates, emphasizing the importance of targeted interventions to address this global health challenge (Table 4).

Table 4. Factors associated with malnutrition by univariate regression.

Variables	OR	95% I.C.	p
Genre (Male)	0.8	[−0.8 - 0.5]	6.7
Diarrhea (Yes)	1.7	[−0.2 - 1.3]	1.3
Vomiting (Yes)	0.4	[−3.6 - 0.8]	4.4
Fever (Yes)	1.0	[−0.7 - 0.7]	9.9
Acute Respiratory Failure (Yes)	1.6	[−0.2 - 1.2]	1.9
Malaria			
Yes	2.5	[0.1 - 1.8]	3.7
Without confirmation by examination	1.1	[−1.8 - 1.5]	9.0
Anaemia (Yes)	0.4	[−1.4 - 0.01]	4.7
Presence of drinking water at home (No)	2.9	[0.01 - 2.5]	7.9
Overcrowded housing (Yes)	1.25	[−0.6 - 0.9]	5.7
First foods you gave your child (Porridge)	0.8	[−0.9 - 0.6]	6.9
Food supplements for children (No)	1.6	[−0.2 - 1.37]	2.0
Traditional Baby Feeding Practices in Your Community (Yes)	1.2	[−0.5 - 0.9]	5.9
Nutrition through industrial foods (Yes)	0.6	[−1.1 - 0.3]	2.6
Difficulties of food diversification (Yes)	0.8	[−0.9 - 0.6]	7.3
Age (month) of diversification of diet			
]4 - 6]	0.1	[−3.6 - −0.4]	0.006
]7 - 9]	0.1	[−3.2 - −0.09]	0.02
Type of food provided in addition to breast milk			
Everything we eat	0.08	[−3.9 - 1.2]	0.0003
Porridge and other foods	0.2	[−2.1 - 0.4]	0.002
Family standard of living			
Pupil	7.5	[NA - 123.2]	9.9
Weak	1.3	[-0.4 - 1.02]	4.3
Child health expenditure FCFA			
[10,001 - 20,000]	1.3	[−0.8 - 1.2]	6.01
[20,001 - 70,000]	2. 1	[−3.8 - 0.6]	3.6
[50,001 - 10,000]	2.9	[−0.04 - 1.9]	4.3

2) ***Multivariate regression results on malnutrition***

Children with diarrhea, malaria, and limited access to drinking water are at an increased risk of malnutrition. Early diversification of diet and receiving food supplements can help mitigate these risks. Children who consume a variety of foods, including those beyond porridge, are less likely to suffer from malnutrition compared to those who rely solely on family meals. (**Table 5**)

Table 5. Factors associated with malnutrition by multivariate regression.

Variables	OR	95% I.C.	p
Diarrhea (Yes)	5.1	[0.4 - 2.8]	0.006
Acute Respiratory Failure (Yes)	1.5	[−0.5 - 1.4]	0.4
Malaria			
Yes	6.2	[0.7 - 3.08]	0.002
Without confirmation by examination	1.0	[−2.04 - 1.6]	0.9
Presence of drinking water at home (No)	1.3	[−1.3 - 2.0]	0.7
Overcrowded housing (Yes)	1.2	[−1.1 - 1.5]	0.7
Food supplements for children (No)	1.7	[−0.6 - 1.8]	0.3
Traditional Baby Feeding Practices in Your Community (Yes)	1.6	[−0.9 - 1.9]	0.5
Age (month) of diversification of diet			
]4 - 6]	0.2	[−3.6 - 1.04]	0.2
]7 - 9]	0.4	[−2.8 - 1.3]	0.4
Type of food provided in addition to breast milk			
Everything we eat	0.03	[−5.3 - −1.4]	0.0009
Porridge and other foods	0.1	[−2.8 - −0.5]	0.005
Family standard of living			
Pupil	6.7	[NA - 95.7]	0.9
Weak	0.7	[−1.4 - 0.7]	0.5
Child health expenditure FCFA			
[10,001 - 20,000]	1.1	[−1.2 - 1.5]	0.8
[20,001 - 70,000]	0. 4	[−3.8 - 1.2]	0.5
[50,001 - 10,000]	1.3	[−1.2 - 1.7]	0.7

4. Discussion

A study of 378 infants in Guera Province, Chad, found that 94% were mixed-breastfed, while only 6% were exclusively breastfed (EBF). These results align with findings from Asoba *et al.* (2019) in Cameroon, which showed a higher prevalence of mixed feeding (60.1%) compared to EBF (22.6%) [43]. The high prevalence of mixed breastfeeding in Chad and Cameroon is likely influenced by a combination of cultural, social, and economic factors. Cultural norms and practices often encourage mixed feeding, while limited access to healthcare and nutrition education can hinder mothers' ability to make informed decisions about infant feeding. Exclusive breastfeeding is the gold standard for infant health, providing numerous benefits. However, mixed breastfeeding may not offer the same level of protection and can increase the risk of malnutrition, particularly in regions with high poverty rates and food insecurity. Addressing these underlying factors is essential for improving infant health and nutrition in these countries [44]-[47].

The study region, with a Global Acute Malnutrition (GAM) rate of 13.0%, is facing a severe malnutrition crisis far exceeding the national average of 8.6% and the WHO's critical threshold of 10%. The SAM prevalence in this study was 1.5%, which is the national prevalence. Our result is below the high alert threshold of 2%; regional disparities are significant, with rates as high as 2.5% in certain areas, including Bahr El Gazal and Wadi Fira, indicating a pressing need for targeted interventions to address acute malnutrition in vulnerable populations [29]. Malnutrition in Chad remains a pressing public health issue, characterized by regional disparities in acute malnutrition rates. Despite existing interventions, ongoing monitoring and evaluation are crucial to ensure their effectiveness in addressing root causes and achieving sustainable improvements. A study conducted in a specific region reveals a prevalence of acute malnutrition exceeding WHO recommendations, highlighting the need for targeted interventions. To effectively combat this crisis, a multifaceted approach is necessary, including strengthening agricultural systems, ensuring equitable access to healthcare, and implementing social safety nets to support vulnerable populations. By addressing these interconnected factors, Chad can make significant strides towards improving nutritional outcomes and reducing the burden of malnutrition [1] [48]-[50].

The stark regional disparities in severe acute malnutrition (SAM) rates within Chad underscore the urgent need for tailored interventions. While existing data offers valuable insights, it's imperative to consider potential limitations, such as sample size, representativeness, and data collection methods. To effectively combat SAM, a comprehensive understanding of its underlying causes, including food insecurity, healthcare access, socioeconomic factors, and cultural practices, is essential. By investigating these determinants, policymakers can develop more targeted prevention and treatment strategies. SAM has severe consequences for child development, including impaired growth, cognitive deficits, and increased mortality. Addressing malnutrition is not only a humanitarian imperative but also a critical investment in human capital. Regular monitoring of SAM prevalence through surveys like SMART is essential for early detection and timely response to emerging hotspots [4] [20] [39] [51]. Targeted nutrition programs are essential in regions with high rates of severe acute malnutrition (SAM). By focusing on prevention, early diagnosis, and appropriate treatment, these programs can significantly improve child health outcomes. Empowering communities to participate in nutrition activities fosters awareness, promotes healthy food practices, and facilitates access to healthcare services [10]. Addressing the root causes of malnutrition requires a coordinated approach involving multiple sectors. Investing in research to better understand the determinants of malnutrition is crucial for developing evidence-based interventions that promote food security, enhance access to healthcare, and support sustainable livelihoods, ultimately improving child health in Chad [8] [43] [52]-[54].

In our analysis of gender-specific malnutrition, boys exhibited a slightly higher prevalence of global acute malnutrition (GAM) than girls, with rates of 9.6% and

5.5%, respectively. Severe malnutrition was uncommon in both groups, but boys again showed a slightly higher rate (1.3%) compared to girls (0.5%). These findings align with the results of the SMART study, which reported higher GAM rates in boys (9.8%) than girls (7.4%) at the national level and in most provinces of Chad [29] [31]. The provided data indicates that in the context of the study, boys experience slightly higher rates of both global acute malnutrition (GAM) and severe malnutrition compared to girls. This trend is consistent with the findings of the SMART study conducted in Chad. While the differences observed between boys and girls are not substantial, they highlight a potential gender disparity in malnutrition within the study population. It's important to consider the factors that may contribute to this disparity, such as cultural norms, feeding practices, and access to healthcare and resources [29] [31] [55]-[59].

To address the gender-specific disparity in malnutrition rates, further research is imperative to identify underlying causes and develop tailored interventions. Socioeconomic factors, cultural norms, and access to resources significantly influence these rates, interacting with gender in complex ways. Understanding these dynamics is crucial for developing effective interventions that address the specific needs of both boys and girls, ultimately improving their physical and cognitive development, education, and future well-being.

The study assessed acute malnutrition rates in Guéra, Chad, using Mid-Upper Arm Circumference measurements, comparing findings with those of neighboring regions in Cameroon. Guéra exhibited a lower prevalence of global acute malnutrition (GAM) at 8.6% compared to Cameroon, respectively 32.6% and 55.5% [43] [60]. The findings highlight a concerning prevalence of acute malnutrition in Guéra, emphasizing the need for urgent interventions to address nutritional needs. The higher rates of severe malnutrition in certain age groups underscore the importance of targeted nutrition programs that focus on vulnerable populations. Several factors might contribute to the observed malnutrition rates. These could include variations in dietary practices, access to healthcare services, socioeconomic conditions, and climatic factors. Further research is warranted to delve deeper into these underlying determinants and inform effective interventions [3] [14] [36] [40].

In this study, we found a global stunting prevalence of 20.1% (95% CI: 16.0 - 24.8) among children under five. This rate is comparable to previous findings by Gibson *et al.* (1991) and Genton *et al.* (1998), who reported prevalence rates of 29% and 27%, respectively [54] [61]. Our analysis also revealed a slight gender disparity, with boys exhibiting a higher rate of stunting (24.4%) than girls (16.8%). Similarly, boys were more likely to experience severe stunting (16.3%) compared to girls (9.8%). These results align with the sex-related trend observed by Genton *et al.* in 1998 [54]. The high prevalence of stunting, particularly among boys, has significant implications for child health and development. Stunting can result in cognitive impairments, physical disabilities, and heightened vulnerability to infections and diseases. Addressing this gender disparity requires targeted interventions that promote gender-sensitive nutrition practices and improve access to healthcare services for boys [19] [20] [41] [43] [52] [62]. To develop effective interventions for stunting, further research is needed to explore the underlying factors that contribute to this condition, especially in boys. Investigating the specific determinants of stunting in boys could help identify targeted interventions to address their unique needs. Additionally, research on the long-term consequences of stunting is important to inform policies and programs aimed at improving the health and well-being of children [60] [63].

Our study revealed a 20.3% prevalence of underweight among children, with males (27.4%) exhibiting a higher rate than females (14.5%). Although severe underweight was less common at 4.5%, males were disproportionately affected (7.7% vs. 1.9% in females). These findings align with those from Burkina Faso in 2022 by Ali Si *et al.*, which reported a 19.0% underweight prevalence among infants, with males having a significantly higher risk (60.2% vs. 9.8% in females) [64]. Several factors may contribute to the higher prevalence of underweight among males in Chad. One possible explanation is that boys may be less likely to be breastfed for as long as girls, or they may not be breastfed as exclusively. This could put them at a higher risk of malnutrition due to the nutritional benefits of breast milk. Additionally, boys may be more likely to consume less nutritious foods or to be fed less frequently than girls. This could be due to cultural or societal factors that prioritize the feeding of girls over boys. Furthermore, parents with boy infants may be less likely to have access to health care services, including immunization and growth monitoring, which can help to prevent and address malnutrition. Poverty and food insecurity may also be more prevalent among families with boys, which could put them at a higher risk of being underweight due to limited access to food and healthcare resources [29] [31] [58] [65]-[67].

The results of this study have important implications for public health policy and practice in Chad. To address the higher prevalence of underweight among males, it is essential to promote exclusive breastfeeding for the first six months and continued breastfeeding for up to two years. Additionally, promoting the consumption of nutritious foods, including complementary foods, among children is crucial. Ensuring that all children have access to essential healthcare services, including immunization and growth monitoring, is another important step. Implementing programs to address poverty and food insecurity can also help to reduce the risk of being underweight among children. Further research is needed to better understand the specific factors that contribute to the higher prevalence of underweight among males in Chad and to develop effective interventions to address this problem [6] [60] [65] [66] [68].

In our study, the prevalence of overweight among the population was notably low at 4.2%. Boys exhibited a slightly higher rate of overweight (5.1%) compared to girls (3.5%). The highest prevalence was observed in the 18 - 24-month age group, reaching 6.1%. Our findings were consistent with those reported by Ayele *et al.* in 2022, which indicated an overweight prevalence of 5.10% in sub-Saharan Africa and 8.80% in the South Africa region among children under five [52].

Additionally, our results aligned with the 3.9% overweight prevalence reported by Sserwanja *et al.* in Uganda in 2021 [69]. The low prevalence of overweight observed in this study is consistent with regional trends reported in sub-Saharan Africa, particularly in South Africa [52] and Uganda [69]. This suggests a regional pattern of lower overweight prevalence in these areas.

The relatively low prevalence of overweight in this population is likely influenced by a combination of factors, including dietary habits, physical activity levels, socioeconomic conditions, and cultural practices. By identifying the specific determinants contributing to this low rate, policymakers and healthcare professionals can develop effective interventions to prevent childhood obesity. Further research is necessary to explore these factors in depth and identify potential risk factors, providing valuable insights for targeted prevention strategies [43] [60] [69]-[72].

The generalizability of these findings may be limited due to the specific characteristics of the study population, which may not have captured the full spectrum of overweight cases, particularly those with mild or moderate levels. Future studies should consider using standardized anthropometric measurements and incorporating additional factors such as socioeconomic status, dietary habits, and physical activity levels to enhance the representativeness and applicability of their results [32] [48] [71]-[74].

The findings presented underscore the complex interplay of factors that contribute to childhood malnutrition. Diarrhea, malaria, and inadequate access to clean water can significantly impact a child's nutritional status. These conditions can lead to nutrient loss, decreased food intake, and impaired absorption, further exacerbating malnutrition [28] [64] [69] [71] [72] [75].

Introducing a variety of foods into a child's diet at an early age is crucial for providing the necessary nutrients for growth and development. This helps to ensure that the child is receiving a balanced intake of macronutrients (proteins, carbohydrates, and fats) and micronutrients (vitamins and minerals). Early diversification can also support the development of a child's taste preferences and acceptance of new foods, which can be beneficial for long-term nutritional health [37] [47] [67].

Food supplements, such as fortified foods or nutritional supplements, can play a vital role in addressing nutrient deficiencies in children at risk of malnutrition. These supplements can provide essential vitamins, minerals, and energy, helping to support growth and development. However, it is important to note that food supplements should be used in conjunction with a balanced diet and not as a substitute for whole foods [76]-[78].

Consuming a variety of foods beyond porridge is essential for ensuring that children receive a wide range of nutrients. A diverse diet can help to prevent nutrient deficiencies and promote optimal growth and development. Encouraging children to explore different food options can also help to cultivate healthy eating habits that can benefit them throughout their lives [50] [79]-[81].

To effectively address childhood malnutrition, it is essential to address the underlying causes, such as diarrhea, malaria, and limited access to clean water. This may involve implementing public health interventions, improving sanitation and hygiene practices, and providing access to healthcare services [82]-[84].

5. Conclusion

This study conducted in Guéra Province, Chad, demonstrated a significant prevalence of malnutrition among infants under five years of age, with boys and older infants exhibiting higher susceptibility, particularly to severe forms. Contributing factors included socioeconomic disparities, suboptimal feeding practices such as inadequate breastfeeding and complementary feeding, and a high burden of infectious diseases. These findings underscore the urgent need for multifaceted interventions. These should include expanding Community-Based Management of Acute Malnutrition programs, integrating nutrition services into routine child health care, improving infant and young child feeding practices, strengthening disease surveillance and response systems, and enhancing socioeconomic conditions through poverty reduction initiatives. These interventions can be effectively integrated into existing national frameworks such as the National Plan for Nutrition and the National Health Development Plan.

Authors' Contributions

NMM, MB, BS, and ASY were responsible for the conception and design of the study as well as project administration. NMM participated in training investigators, collecting and processing data, and measuring anaemia. NMM and DSM were responsible for statistical analysis and interpretation of results. NMM and DSM wrote the original draft. All authors reviewed the first draft and approved the final version of the paper for submission. MB, BS, and ASY oversee all steps.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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