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The magnitude and risk factors for concurrent anthropometric and nutritional deficiency among children aged 6 to 59 months in liberia: A Multi-Level analysis using the 2019 Liberia demographic health survey (LDHS) data

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Abstract

Objective This study aimed to investigate the magnitude and risk factors associated with concurrent anthropometric and nutritional deficiencies among children aged 6 to 59 months in Liberia.

Materials and methods We conducted a multilevel analysis using data from the 2019 Liberia Demographic and Health Survey (LDHS) to gain a comprehensive understanding of the problem. The study examined the prevalence of common problems, such as stunting, wasting, and anaemia, among children in Liberia to gain a deeper understanding of the issue. This study employed four different regression models. These models included panel mixed-effects Poisson regression, panel mixed-effects logistic regression, Poisson regression, and conditional fixed-effects regression.

Results Our findings showed that, among children aged 6–59 months in Liberia, the prevalence of stunting was 31.98%. Additionally, wasting was 6.84%, underweight was 11.97%, and anaemia was 34.09%. Notably, children aged 24–35 months faced a significantly higher risk, with a 59.2% increased incidence rate of concurrent deficiencies (IRR = 1.592, $p < 0.05$). Female children had a 22.6% lower incidence of deficiencies compared to males (IRR = 0.774, $p < 0.05$). Household wealth status showed a strong protective effect, with children in the wealthiest households experiencing a 46.3% lower risk of multiple deficiencies (IRR = 0.537, $p < 0.01$). Complete immunisation was linked to a 37.8% reduction in the incidence of deficiencies (IRR = 0.622, $p < 0.05$). Furthermore, concurrent anaemia and stunting (CAS) were present in 37.0% of cases, with children in the wealthiest households having 87% lower odds (AOR = 0.130, $p = 0.024$).

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Conclusion By implementing effective interventions that promote proper nutrition and growth, policymakers and stakeholders can work toward improving the health and well-being of children in Liberia and reducing the burden of concurrent anthropometric and nutritional deficiencies. We therefore recommend that policymakers and practitioners in Liberia prioritize cluster-specific interventions to promote child health, given the high variability at the cluster level.

Keywords Child malnutrition, Concurrent anthropometric deficiencies, Nutritional deficiencies, Stunting, Wasting, Anaemia, Risk factors, Multilevel analysis, Demographic and health survey, Liberia

Introduction

Child malnutrition remains a serious global health problem, especially in low- and middle-income countries where vulnerable groups face systemic obstacles to growth and development [1]. Undernutrition is responsible for nearly half of all child deaths worldwide, emphasizing its severe impact [2, 3]. Besides its immediate health effects, malnutrition has long-term impacts on a child's physical growth, cognitive development, and overall well-being [4]. To monitor and evaluate nutritional status, standard indicators like stunting, wasting, and underweight are commonly used [5]. Recognizing the co-occurrence of anthropometric and nutritional deficiencies is essential for developing targeted interventions and effective public health policies [6]. This study seeks to examine the extent and determinants of concurrent nutritional and anthropometric deficits among children aged 6 to 59 months, addressing an important gap in knowledge and providing evidence to inform context-specific policies and programmes [2].

Liberia, situated in West Africa, faces persistent challenges that increase the risk of child malnutrition, such as widespread poverty, food insecurity, the aftermath of prolonged civil conflict, and a fragile healthcare system [7]. These socioeconomic and environmental factors create a complex landscape for child health and nutrition. The unique features of Liberia make it an important context for examining the coexistence of anthropometric and nutritional deficiencies in children. This study investigated the prevalence and causes of abnormal body parameters and nutritional deficiencies in children aged 6 to 59 months in Liberia. While stunting, wasting, and anaemia are serious conditions individually, studying their coexistence is essential because multiple nutritional issues often occur together in the same child, heightening health risks [4, 6]. Children who are both stunted and anaemic, for example, face greater threats to physical growth, cognitive development, immune function, and survival than those experiencing only one deficiency [8, 9]. Analysing these overlapping conditions helps identify the most vulnerable groups, uncover common underlying risk factors such as poverty, poor diet, and infections [5], and supports more effective integrated interventions [10]. Focusing solely on individual deficiencies might neglect the broader impact of combined health problems within affected populations.

This study provides a detailed analysis of concurrent anthropometric and nutritional deficiencies in children, contrasting with earlier research in Liberia and West Africa that primarily examined individual nutritional issues, such as stunting, wasting, or anaemia, in isolation [5, 10]. It employs robust multi-level modeling to consider both individual and community-level effects, revealing significant community variability that previous studies often overlooked. Our research provides targeted insights for developing integrated interventions to effectively combat child malnutrition in Liberia by analyzing both combined and separate deficiencies and identifying key risk factors, including socioeconomic, maternal, and environmental influences. This essential knowledge can guide policies aimed at achieving SDG targets related to hunger and health in post-conflict and economically challenged settings.

Variations in anthropometric indices can have lasting effects on a child's physical health, cognitive development, and overall well-being [8]. It is essential to identify the core elements of this issue to develop effective interventions that can enhance children's health and nutritional status in Liberia [10]. The unique socioeconomic and environmental characteristics of Liberia, including limited healthcare access, food insecurity, and high rates of infectious diseases, make it a vital case study for investigating child malnutrition [11]. This study aimed to assess this issue by analyzing individual, community, and regional factors.

We emphasize the negative effects of child malnutrition on health, cognitive development, physical growth, and future opportunities for Liberian children affected by prolonged civil conflict, limited healthcare, and widespread poverty. This aligns with Liberia's commitment to the United Nations' Sustainable Development Goals, specifically Goal 2 (Eliminating Hunger) and Goal 3 (Promoting Health and Well-being). This study aims to offer accurate, up-to-date data to support evidence-based strategies for addressing child malnutrition nationwide. This data can help governments, healthcare professionals, and humanitarian organizations allocate resources more efficiently and target interventions more effectively. The study aims to answer two main questions: What is the prevalence of concurrent anthropometric and nutritional deficiencies among children aged 6 to 59 months in Liberia? And how do individual, household, community, and regional factors influence the risk of these concurrent deficiencies in Liberian children?

Materials and methods

The Liberia Demographic and Health Survey provided information on the health and nutritional status of children in Liberia. The categorization of undernutrition in children was performed using height-for-age (HAZ), weight-for-age (WAZ), and weight-for-height (WHZ) standard deviations (SDs) from the World Health Organization (WHO), also known as z scores, to determine stunting, underweight, and wasting, respectively. Anaemia was defined as a haemoglobin level less than 11 g/dl. The study used two outcome variables originally defined by Geda, Feng, Henry, Lepnurm, Janzen, and Whiting and adopted from their 2021 study on nutritional deficiencies in Ethiopian children [12]. Multiple nutritional deficiencies were measured by a combination of wasting, underweight, stunting, anaemia, and concurrent anaemia and stunting (CAS). In the main analysis, the value of "1" was assigned if a child had any of the three anthropometric deficiencies (stunting, underweight, or wasting) or anaemia, and "0" if the child experienced none of the four nutritional problems.

For the secondary analysis, CAS was the outcome variable. For CAS, the value of "1" was used if a child was both anaemic and stunted, and "0" otherwise; thus, the outcome variable, concurrent anaemia and stunting (CAS), was constructed as a binary indicator. A child was coded as having CAS (value = 1) if they were both stunted (height-for-age z-score below − 2 SD) and anaemic (haemoglobin level < 11 g/dL), and as not having CAS (value = 0) if they had neither or only one of these conditions. This combined indicator captures children experiencing both chronic undernutrition and micronutrient deficiency simultaneously, reflecting a higher-risk subgroup with potentially compounded health consequences. The key study variables and their operational definitions are summarized in Table 1 (see appendix).

The selection of the explanatory variables for this research was based on the following characteristics: child-level variables (child age in months, sex of child, preceding birth interval, birth order number), household-level variables (respondents' current age, religion, wealth index, highest educational level, currently breastfeeding), childcare practices (duration of breastfeeding), and community-level variables (native language of respondent) that were used in other studies, along with the availability of variables in the dataset and statistical validity. We included additional explanatory variables such as entries in the immunization roster, type of toilet, time to reach the water source, whether the child was given plain water, respondent occupation, vitamin A supplementation in the last six months, and shared toilet facilities in our model.

We analyzed the data using Stata 17. Analyses were weighted to account for sampling probabilities, and the stratification and clustering of the data were taken into consideration. Descriptive analysis was conducted to examine the characteristics of the study sample. All descriptive analyses and single-level regression models in this study were weighted using the sampling weights provided by the 2019 Liberia Demographic and Health Survey (LDHS) to ensure national representativeness. However, for the multilevel (mixed effects) models, weights were not directly applied because standard multilevel modeling procedures in Stata do not easily accommodate complex survey weights at multiple levels. As a result, multilevel analyses were performed without weighting, and the findings should be interpreted with this limitation in mind.

We used four regression models, including Poisson regression, mixed-effects Poisson regression, conditional fixed-effects regression, and mixed-effects logistic regression, to thoroughly examine the factors influencing concurrent anthropometric and nutritional deficiencies. The Poisson regression model is well-suited for analyzing rare event data and provides consistent estimates under the assumption of equi-dispersion [13]. Due to the hierarchical structure of the dataset, where children are nested within families and communities, the mixed-effects Poisson regression incorporates random effects to address unobserved heterogeneity and intra-cluster correlations [14]. Moreover, the conditional fixed-effects regression reduces unobserved time-invariant confounding within clusters by focusing on within-cluster variance [15]. Finally, the mixed-effects logistic regression is used for the binary outcome of concurrent anaemia and stunting (CAS), allowing the model to incorporate both fixed and random effects, thereby improving the estimation of associations in multilevel data [16]. We employed multiple statistical models to capture different aspects of the data, account for clustering and unobserved differences within communities, and provide robust, reliable estimates of parameters related to nutritional deficiencies. These models enhance our analytical approach by addressing both fixed and random sources of variation, which aligns with the multilevel nature of the data.

Ethical clearance

Demographic and Health Surveys (DHSs) have been conducted in many countries. DHS is a program that collects and shares nationally representative data on key demographic and health indicators. To access the dataset, we first applied to the Demographic and Health Surveys (DHS). It took about two months to receive the data after submission. The dataset was provided in response to our application. During the process, we had to outline relevant information and justify the research purpose. DHS verified that the dataset met ethical and privacy standards before granting access. This dataset includes comprehensive socioeconomic, health, and demographic data. We did not perform direct data collection from participants. However, ethical standards were maintained by using secondary data from the 2019 Liberia Demographic and Health Survey (LDHS). The LDHS data collection received prior ethical approval from the appropriate institutional review boards, and informed consent was obtained from all participants during the initial survey. The dataset shared with researchers was fully anonymized, ensuring confidentiality and privacy for all individuals.

Results

Table 4 (see appendix) shows the proportion of children aged 6–59 months with stunting, wasting, underweight, or anaemia based on demographic characteristics. Overall, malnutrition remains a major public health issue among Liberian children in this age group. Nearly one-third are stunted (31.98%), and more than a third are affected by anaemia (34.09%). Although wasting is less common overall (6.84%), specific subgroups face higher risks. For example, children aged 24–35 months showed a statistically significant increase in the incidence of multiple deficiencies (IRR = 1.59, $p < 0.05$). Although the data show a 50.00% prevalence of wasting among children aged 24–35 months, this figure is based on a very small sample size ($n = 2$). Therefore, it should not be regarded as a reliable indicator of vulnerability in this age group. Caution is recommended when interpreting this finding, as the limited sample size affects both statistical reliability and the broader applicability of the result.

Moreover, male children tend to have higher rates of stunting and underweight, while females show slightly higher rates of anaemia. Studies suggest that male children may have higher nutritional needs and different biological susceptibilities, which could potentially explain these sex differences [17]. Socioeconomic factors play a key role, as children from the poorest households are more likely to be stunted and anaemic. Conversely, children in the richest quintile have an 87% lower chance of suffering from both anaemia and stunting (AOR = 0.13, $p < 0.05$). Full immunization acts as a protective factor, reducing the occurrence of multiple nutritional deficiencies by nearly 38% (IRR = 0.62, $p < 0.05$). These findings emphasize the need for targeted, equity-focused strategies that address both individual and combined nutritional deficiencies.

Table 2, in the appendix, presents the results of the chi-square analysis examining the relationships between explanatory variables and the simultaneous presence of stunting and anaemia. According to Table 2, the study identified strong associations between specific characteristics and the co-occurrence of these conditions in children aged 6–59 months in Liberia. Notably, receiving vitamin A within the past 6 months emerged as a significant factor ($p < 0.05$). This highlights the potential of targeted nutritional interventions to reduce the combined occurrence of stunting and anaemia, underscoring the ongoing importance of comprehensive vitamin supplementation programs to improve child health. As shown in Table 2, among childcare practices, including names on the immunization list, was found to be a very important factor related to both stunting and anaemia occurring together ($p < 0.001$). This finding emphasizes the critical role of organized immunization programs in decreasing the prevalence of these health issues among children in Liberia.

Effective immunization programs are crucial for enhancing children's overall health and well-being. Additionally, providing plain water for children is critically important, as it is associated with both stunting and anaemia co-occurring ($p < 0.001$). This finding highlights the need for further investigation into water-related practices, sanitation, and hygiene standards. These factors should be considered when developing targeted interventions to improve water quality and hygiene, which may influence children's health. However, further research is needed to confirm the direction and magnitude of this relationship. Concerning community-level factors, the specific type of residential area showed a marginally significant relationship ($p < 0.10$) with the simultaneous occurrence of stunting and anaemia.

The findings of the multilevel regression analysis, as shown in Table 3 (appendix), demonstrate the linkage between concurrent anthropometric and nutritional deficiencies in children aged 6–59 months in Liberia. The research employed Poisson regression, conditional fixed-effects regression, mixed-effects Poisson regression, and mixed-effects logistic regression to systematically identify consistent predictors across various model parameters. Essential findings indicate substantial demographic, social, and health-related factors that interact to affect child nutritional outcomes. The random effects at the cluster level were highly significant ($p < 0.001$), confirming that unobserved community-level factors have a substantial impact on dietary outcomes. This validates the application of multilevel models and suggests the potential value of decentralized, context-specific interventions to address unobserved community-level influences on nutrition [10].

Child-level factors were found to be important. Age consistently predicted dietary deficiencies, especially in children aged 24–35 months, who were much more prone to multiple deficiencies. This age coincides with the transition from breastfeeding to complementary foods, a period often associated with inadequate nutrient intake and increased susceptibility to infections [18]. The Poisson regression model showed a 59.2% increase in incidence (IRR = 1.59, $p < 0.05$), while the conditional fixed-effects model indicated an increased risk (AOR = 1.33), although it was not statistically significant. This sensitivity is related to dietary changes during the post-weaning phase. It aligns with earlier research, which highlights that the ages of 24–35 months are a critical stage for child growth and nutritional interventions [6, 12]. Sex differences were also significant across the models. Female children had a 22.6% lower incidence of deficiencies compared to males (IRR = 0.77, $p < 0.05$, using a Poisson model). They were less likely to experience concurrent stunting and anaemia in the fixed-effects model (AOR = 0.98, $p < 0.001$). This finding supports evidence suggesting a biological and behavioral advantage for females in early infancy nutritional outcomes [17].

The conditional fixed-effects model demonstrated that children born following a birth interval of at least 24 months exhibited significantly improved nutritional outcomes (AOR = 0.43, $p < 0.001$). This finding aligns with [4], suggesting a possible role of adequate birth spacing in improving maternal caregiving capacity and child nutritional outcomes. This variable was not significant in the Poisson model, indicating that fixed-effects models may better capture within-cluster differences. Health interventions such as vitamin A supplementation and vaccination showed varied yet substantial effects. Children who had received vitamin A in the previous six months had lower odds of deficiencies in the fixed-effects model (AOR = 0.75, $p < 0.001$). However, this association was not significant in the Poisson regression. Immunization status was one of the most impactful protective factors. Fully immunized children experienced a 37.8% decrease in deficiency frequency (IRR = 0.62, $p = 0.03$, Poisson model) and a 12.4% reduction in odds in the mixed-effects model (AOR = 0.88, $p < 0.001$). These results support other studies linking vaccination coverage with improved nutritional outcomes [19, 20].

Maternal traits had a substantial influence. Children of mothers aged 36 and older showed increased nutritional sensitivity, with a 34.5% higher incidence (IRR = 1.35, $p < 0.10$) in the Poisson model and a 99.2% increase in odds in the fixed-effects model (AOR = 1.99, $p < 0.001$). This may reflect possible biological or socioeconomic disadvantages among older mothers, a trend previously noted in the literature [21]. Maternal education offered inconsistent protective benefits across models, indicating that knowledge alone might be insufficient without proper access to health and nutrition services [22]. Religion became a significant factor. In the Poisson model, children from Muslim households experienced a 22.4% reduction in deficiency incidence (IRR = 0.78, $p < 0.10$), while the fixed-effects model showed a markedly lower odds ratio (AOR = 0.24, $p < 0.001$). These results may be influenced by unmeasured factors, including cultural practices or dietary habits, which require further qualitative research to clarify.

Socioeconomic status regularly offers protection. Children from affluent families showed a 46.3% lower incidence rate in the Poisson model (IRR = 0.54, $p < 0.05$) and a 74% reduced likelihood of simultaneous anaemia and stunting in the mixed-effects logistic model (AOR = 0.13, $p < 0.05$). These results point out the robust relationship between household wealth and child health outcomes, primarily due to improved access to nutrition, healthcare, and sanitation [11]. Environmental and sanitation factors showed less consistent but still significant associations. Breastfeeding was unexpectedly associated with increased odds of deficiencies in the fixed-effects model, which may reflect reverse causality or unmeasured confounding, such as delays in complementary feeding. Access to water and sanitation variables, such as the time required to reach a water source and the availability of shared toilet facilities, showed inconsistent effects, necessitating further investigation into hygiene-related factors that impact child malnutrition.

Discussion of findings

Our findings align with those of [9], who reported a 72.6% prevalence of anaemia among Southeast Asian children aged 6–36 months, with key predictors including young age, maternal anaemia, low height-for-age, low family income, maternal education, unboiled water intake, and recent fever. To combat regional anaemia and malnutrition, urgent comprehensive actions were recommended. Similarly [20], found a 21.4% prevalence of vitamin A deficiency among Brazilian children aged 6–24 months, noting that extended breastfeeding was protective while low birth weight increased vulnerability [17]. also observed significant sex-based differences in dietary diversity among Indian adolescents, with boys consuming more protein- and vitamin-rich foods than girls at age 15. To address sex-based nutritional gaps, the study suggested targeted interventions. The N@C programme in Bangladesh, as evaluated by [23], was shown to improve maternal and child nutrition indicators, including prenatal care uptake and dietary diversity. Local planning and multi-sectoral approaches contributed to these improvements.

[24] linked child undernutrition in Tanzanian fishing communities to low birth weight, inadequate immunisation, limited maternal education, and poor access to health services. We recommend enhancing healthcare and empowering mothers through education. In Ghana [21], reported a 64.3% vitamin A supplementation rate

but highlighted a lack of nutritional awareness among caregivers as a significant barrier to uptake. The study emphasized the importance of caregiver nutrition education to increase vitamin A supplementation [19]. examined vaccination status and child nutrition in 16 countries. Vaccination is fundamental for child health, and incomplete immunization is associated with underweight, wasting, and stunting. On Leti Island, Indonesia [25], found that exclusive breastfeeding and improved healthcare access significantly reduced childhood stunting. The study advised increasing healthcare access and regular health visits for mothers and children [22]. demonstrated that maternal education of more than 10 years was associated with reduced rates of stunting, underweight, and wasting in Malawi, Tanzania, and Zimbabwe. The study highlighted the importance of maternal education in infant nutrition [26]. showed that the American College of Cardiology/American Heart Association (ACC/AHA) criteria identified a higher incidence of hypertension among young adults in Albania compared to the Report of the Joint National Committee (JNC7) guidelines. Age, education, wealth, number of living children, health insurance status, and sex were associated with hypertension.

Our findings align with previous studies across sub-Saharan Africa, where similarly high rates of malnutrition have been reported, such as the 72.6% anaemia prevalence among Southeast Asian children [9] and high rates of concurrent stunting and wasting in Ethiopia and Uganda [4, 6]. However, our observed stunting prevalence of 31.98% and anaemia prevalence of 34.09% in Liberia are somewhat lower than the figures reported by [10] during post-conflict periods. The increased vulnerability among children aged 24–35 months may result from biological factors, including weaning from breastfeeding and increased exposure to infections at this stage, along with changing dietary practices that may not meet nutritional needs [8]. Additionally, male children often experience higher rates of malnutrition, possibly due to higher physiological demands for growth, different care practices, or cultural feeding preferences that might favor female children in some contexts [17]. By placing our results within this broader context, we highlight the persistent and complex nature of child undernutrition in Liberia, emphasizing the need for age- and sex-specific interventions.

The findings of significant cluster-level variation and specific risk factors for concurrent nutritional deficiencies in Liberian children have important policy implications. They suggest that policymakers should develop interventions tailored to each community's unique characteristics instead of implementing uniform national policies. For example, cluster-specific interventions could include targeted nutrition education for mothers in high-risk areas, localized supplementation programs, improved access to health services, and community-led efforts to strengthen water and sanitation infrastructure. However, implementing these tailored approaches faces barriers, including limited financial resources, shortages of trained health personnel, logistical challenges in reaching remote communities, and potential political and administrative fragmentation that can hinder coordination across regions. Additionally, collecting and maintaining detailed local data necessary for designing and monitoring cluster-specific interventions can overburden already fragile health systems. Overcoming these barriers will require ongoing investment, capacity-building, and close collaboration between government agencies, local leaders, and international partners to ensure that interventions are both culturally appropriate and sustainable.

This study has several limitations. First, it relies on cross-sectional data from the 2019 Liberia Demographic and Health Survey, which limits causal inference. Second, although multilevel modelling enhances estimation by addressing clustering, residual confounding may still exist due to unmeasured variables such as dietary intake or maternal mental health. Third, certain subgroups in the dataset (e.g., children aged 24–35 months in some analyses) had very small sample sizes, which restricts statistical power and the reliability of estimates in these strata. Fourth, anaemia was measured solely using haemoglobin levels without specifying type or cause, thereby limiting interpretability. Lastly, while this study considers multiple nutritional outcomes, the exclusion of other micronutrient deficiencies or environmental exposures may underestimate the true burden of malnutrition.

Conclusion and recommendations

This study revealed that many Liberian children aged 6–59 months face both anthropometric and nutrient deficiencies, with nearly one-third experiencing stunting and over one-third affected by anaemia. Children aged 24 to 35 months and males were identified as the most vulnerable groups, with socioeconomic factors such as household wealth and maternal education playing a significant role in nutritional outcomes. The results also showed notable variation at the cluster level, indicating that unobserved community-specific factors have a significant influence on nutritional health.

Based on these findings, we recommend that policymakers consider developing and testing cluster-specific interventions tailored to the varied needs of local communities. These could include targeted nutrition education, enhanced immunisation coverage, and upgraded water and sanitation infrastructure, especially for high-risk age groups and male children. Evidence-based interventions, including micronutrient supplementation, community health programs, and improved feeding

Table 1 Operational definitions of key variables

Variable	Operational Definition
stunting	Height-for-age z-score below −2 SD (WHO standard).
wasting	Weight-for-height z-score below −2 SD (WHO standard).
underweight	Weight-for-age z-score below −2 SD (WHO standard).
anaemia	The haemoglobin level is less than 11 g/dL.
CAS (concurrent anaemia and stunting)	Child coded as "1" if both stunted and anaemic, "0" otherwise.
wealth index	Composite measures from household assets, housing materials, and access to water/sanitation, categorized into quintiles (poorest, poorer, middle, richer, richest).
maternal education	Highest schooling attained, classified as no education, primary, secondary, or higher.
currently breastfeeding	Whether the child was still receiving breast milk at the time of the survey.
vitamin A supplementation	Whether the child received a vitamin A dose in the past six months.
shared toilet facilities	Sanitation facilities shared with other households (yes/no).
place of residence	Urban or rural, based on DHS classification.
time to water source	Minutes reported to reach the primary water source.
child's age and sex	Recorded in months; sex as male or female.
birth order	Sequence number of a child among siblings.
immunization status	Classified as partially, fully immunized, or additional vaccinations recorded.

Source: Authors' construct (2023)

practices, have shown promise and cost-effectiveness in similar contexts [18, 27]. However, successful implementation will require addressing challenges such as resource limitations, logistical issues, and the need for local data to inform actions. Continued investment in data systems, community engagement, and integrated health and nutrition strategies will be crucial to effectively reducing child malnutrition in Liberia. Future studies should employ longitudinal designs to investigate the causal relationships between identified risk factors and nutritional outcomes, as well as to examine how seasonal changes, infections, and dietary patterns contribute to concurrent deficiencies. Additionally, qualitative research could provide a deeper understanding of the cultural, behavioral, and community-specific factors affecting child nutrition in Liberia.

Table 2 Results of chi-square analysis for associations between the explanatory variables and concurrent stunting and anaemia

Characteristics	No CAS *N* (%)	CAS *N* (%)	Chi-square
Child Level			0.96
Child's age in months			
6–23 months	102 (19.39)	424 (80.61)	
24-35months	0 (0.00)	4 (100.00)	
Sex of the child			
male	353 (62.04)	216 (37.96)	
female	363 (63.13)	212 (36.87)	
Preceding birth interval in months			
6–11 months	3 (60.00)	2 (40.00)	1.15
12–23 months	60 (57.69)	44 (42.31)	
24 + months	541 (63.05)	317 (36.95)	
Birth order number			
first	109 (63.01)	64 (36.99)	0.02
second and above	607 (62.51)	364 (37.49)	
Vitamin A in the last 6 months			
no	428 (65.64)	224 (34.36)	6.79**
yes	286 (58.73)	201 (41.27)	
do not know	2 (40.00)	3 (60.00)	
Household Level			
Respondents' current age			
15–25 years	258 (62.17)	157 (37.83)	0.13
26–35 years	309 (63.19)	180 (36.81)	
36 years and above	149 (62.08)	91 (37.92)	
Religion			
Orthodox	132 (66.00)	68 (34.00)	1.21
Muslim	584 (61.86)	360 (38.14)	
Wealth index combined			
poorest	256 (64.32)	142 (35.68)	6.89
poorer	202 (61.96)	124 (38.04)	
middle	119 (56.40)	92 (43.60)	
richer	88 (69.84)	38 (69.84)	
richest	51 (61.45)	32 (38.55)	
Highest level of education			
no education	327 (63.01)	192 (36.99)	1.98
primary	205 (61.75)	127 (38.25)	
secondary	170 (61.82)	105 (38.18)	
higher	14 (77.78)	4 (22.22)	
Currently breastfeeding			
never	98 (57.65)	72 (42.35)	2.08
breastfeed	618 (63.45)	356 (36.55)	
Respondent's Occupation			
not working	219 (64.04)	123 (35.96)	3.99
agriculture sector	111 (56.35)	86 (43.65)	
other sectors	385 (63.85)	218 (36.15)	
Child Care Practices			
Duration of breastfeeding			
ever breastfed, not currently breastfeeding	92 (57.14)	69 (42.86)	2.41
never breastfed	6 (66.67)	3 (33.33)	
still breastfeeding	618 (63.45)	356 (36.55)	
Toilet facilities shared with other households			
no	113 (60.11)	75 (39.89)	1.01
yes	237 (64.05)	133 (35.95)	

Table 2 (continued)

Characteristics	No CAS *N* (%)	CAS *N* (%)	Chi-square
not a dejure resident	8 (57.14)	6 (42.86)	
Entries in the immunization roster			
partially immunized	2518 (61.80)	1262 (38.20)	28.11***
fully immunized	513 (68.64)	175 (31.36)	
additional vaccinations	29 (80.00)	6 (20.00)	
Gave the child plain water			
no	542 (86.54)	148 (13.46)	58.33***
yes	1543 (58.81)	906 (41.19)	
Community Level			
Native language of the respondent			
English	3,925 (68.81)	1,779 (31.19)	
Type of place of residence			
urban	1,335 (70.49)	559 (29.51)	3.70**
rural	2590 (67.98)	1220 (32.02)	
Toilet type			
others	2086 (69.35)	922 (30.65)	0.86
no facility/bush/field	1839 (68.21)	857 (31.79)	
Time to get to the water source			
less than 30 min	3022 (68.60)	1383 (31.40)	2.87
31–60 min	301 (66.74)	150 (33.26)	
1 h and above	602 (70.99)	246 (29.01)	

*** $p < 0.0$, ** $p < 0.05$, * $p < 0.1$.

Source: Authors' construct (2023)

Table 3 Estimated regression models showing factors associated with nutritional deficiencies

Characteristic	Model 1 AOR	Model 2 AOR (*p*-value)	Model 3 IRR	Model 4 (CAS) AOR
Random Effect				
cluster			6.51e-12***	0.351
Fixed Effect				
Age of the child				
24-35months	1.592**		1.330	
Sex of the child				
female	0.774**	0.984***	0.877	0.628
Preceding birth interval				
12–23 months	0.91		1.24	1.42
24 + months	0.57	0.43***	0.93	
Vitamin A in the last 6 months				
yes	0.91	0.75***	0.93	1.84
do not know	1.31		1.24	
Mother's age				
26–35 years	1.09	1.27***	1.17	0.91
36 years and above	1.35*	1.99***	1.38	0.54
Religion				
Muslim	0.78*	0.24***	0.87	0.86
Wealth index				
poorer	0.92	1.29***	1.03	1.06
middle	0.87	1.51***	0.98	1.01
richer	0.54**	0.82***	0.68	0.13**
richest	0.69	0.46***	0.73	0.26
Mother's education				
primary level	1.13	1.32***	1.17	0.94
secondary and above	1.06	1.04***	0.98	1.34
Currently breastfeeding				
breastfeed	1.03	0.98***	0.89	0.40
Occupation				
agriculture sector	1.26	1.93***	0.93	1.76
other sectors	1.05	1.13***	0.90	0.68
Toilet facilities are shared with others				
yes	0.86	1.10***	1.08	1.05
not a dejure	1.47	0.29***	1.81	
Immunization				
fully immunized	0.62**	0.88***	0.89	1.16
Gave the child plain water				
yes	0.95	0.99***	1.03	0.44
Residence				
rural	0.96		0.92	0.31*
Time to get to the water source				
31–60 min	0.97	1.09***	1.21	0.87
1 h and above	0.86	1.35***	1.00	0.82
Constant	0.00***		1.65	95.69***

*** $p<0.01$, ** $p<0.05$, * $p<0.1$. All analyses for conditional fixed-effects regression were weighted. Model 1 is the Poisson regression, Model 2 is the Conditional Fixed-Effect regressio, Model 3 is the Panel Mixed Effects Poisson regression and Model 4 is the Mixed Effect Logistic regression. *AOR* Adjusted Odds Ratio, *IRR* Incidence Rate Ratio

Source: Authors' construct (2023)

Table 4 Proportion of children (6–59 months) with stunting, wasting, underweight or anaemia from demographic characteristics

Characteristic	Stunting *N* (%)	Wasting *N* (%)	Underweight *N* (%)	Anaemia *N* (%)
Child Level				
Child's age in months				
6–23 months	134 (26.48)	35 (6.89)	75 (14.71)	386 (73.38)
24-35months	2 (50.00)	0 (0.00)	1 (25.00)	4 (100.00)
Sex of the child				
male	402 (33.53)	18 (7.09)	39 (15.23)	198 (34.80)
female	380 (30.50)	17 (6.59)	37 (14.34)	192 (33.39)
Preceding birth interval (months)				
6–11 months	2 (100.00)	0 (0.00)	2 (100.00)	1 (20.00)
12–23 months	17 (36.96)	6 (13.04)	9 (19.15)	42 (40.38)
24 + months	94 (24.42)	27 (6.98)	55 (14.18)	286 (33.33)
birth order number				
first	23 (30.26)	2 (2.63)	10 (13.16)	60 (34.68)
second and above	113 (26.04)	33 (7.57)	66 (15.07)	330 (33.99)
Vitamin A in the last 6 months				
no	68 (25.00)	24 (8.82)	44 (16.06)	204 (31.29)
yes	67 (28.51)	11 (4.64)	32 (13.50)	183 (37.58)
do not know	1 (33.33)	0 (0.00)	0 (0.00)	3 (60.00)
Household Level				
Respondent's current age				
15–25 years	55 (29.41)	6 (3.68)	26 (13.90)	125 (35.51)
26–35 years	49 (23.11)	16 (7.92)	30 (14.08)	163 (33.33)
36 years and above	32 (28.83)	13 (8.84)	20 (17.54)	102 (33.66)
Religion				
Orthodox	26 (33.33)	8 (10.13)	12 (15.19)	59 (29.50)
Muslim	110 (25.46)	27 (6.24)	64 (14.71)	331 (35.06)
Wealth index combined				
poorest	297 (12.15)	11 (6.43)	30 (17.54)	127 (31.91)
poorer	227 (33.38)	10 (6.76)	24 (16.11)	109 (33.44)
middle	152 (31.93)	8 (7.92)	14 (13.73)	88 (41.71)
richer	79 (28.01)	5 (9.43)	5 (9.43)	36 (28.57)
richest	27 (15.88)	1 (2.56)	3 (7.69)	30 (36.14)
Highest educational level				
no education	341 (32.85)	16 (6.87)	41 (17.60)	171 (32.95)
primary level	254 (34.23)	13 (8.90)	22 (14.86)	117 (35.24)
secondary and above	187 (28.12)	6 (4.51)	13 (9.77)	102 (34.81)
Currently breastfeeding				
no	352 (33.72)	6 (7.14)	9 (10.71)	64 (37.65)
yes	430 (30.69)	29 (6.78)	67 (15.58)	326 (33.47)
Respondent's occupation				
not working	205 (29.16)	10 (6.99)	10 (6.99)	114 (33.33)
agriculture sector	137 (31.93)	6 (6.06)	6 (6.06)	81 (41.12)
other sectors	437 (33.36)	19 (7.06)	19 (7.06)	194 (32.17)
Childcare practices				
Duration of breastfeeding				
ever breastfed, not currently breastfeeding	500 (36.15)	6 (7.41)	160 (11.52)	62 (38.51)
never breastfed	17 (45.95)	0 (0.00)	4 (10.53)	2 (22.22)
still breastfeeding	265 (25.85)	29 (6.78)	131 (12.63)	326 (33.47)
Toilet facilities shared with other households				
no	140 (29.60)	7 (7.95)	9 (10.00)	303 (28.56)
yes	234 (30.27)	11 (6.88)	24 (15.00)	477 (26.30)
not a dejure resident	15 (39.47)	1 (16.67)	2 (33.33)	20 (15.04)

Table 4 (continued)

Characteristic	Stunting *N* (%)	Wasting *N* (%)	Underweight *N* (%)	Anaemia *N* (%)
Entries in immunization roster				
partially immunized	543 (31.90)	5 (12.50)	208 (12.14)	356 (34.87)
fully immunized	92 (36.36)	0 (0.00)	44 (17.05)	33 (27.97)
Gave the Child Plain Water				
no	91 (27.91)	2 (8.00)	28 (8.48)	20 (12.82)
yes	364 (31.24)	33 (6.78)	161 (13.68)	370 (37.45)
Community Level				
Native language of the respondent				
English	782 (31.98)	35 (6.84)	295 (11.97)	390 (34.09)
Type of place of residence				
urban	228 (28.79)	11 (7.24)	63 (10.18)	119 (33.90)
rural	554 (33.51)	24 (6.67)	213 (12.78)	271 (34.17)
Toilet type				
others	389 (30.30)	68 (5.28)	158 (12.21)	199 (34.79)
no facility/bush/field	393 (33.85)	37 (3.17)	137 (11.71)	191 (33.39)
Time to get to the water source				
less than 30 min	631 (33.07)	90 (4.70)	229 (11.92)	1178 (26.74)
31–60 min	59 (28.50)	6 (2.88)	25 (12.02)	133 (29.49)
1 h and above	92 (27.88)	9 (2.69)	41 (12.24)	221 (26.06)

Source: Authors' construct (2023)

Appendix

Tables 1, 2, 3, and 4.

Abbreviations

DHS	Demographic and Health Survey
LDHS	Liberia Demographic and Health Survey
HAZ	Height–for–Age Z–score
WAZ	Weight–for–Age Z–score
WHZ	Weight–for–Height Z–score
CAS	Concurrent Anaemia and Stunting
IRR	Incidence Rate Ratio
AOR	Adjusted Odds Ratio
SD	Standard Deviation
WHO	World Health Organization
SDGs	Sustainable Development Goals

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Author contributions

E.G.G. - conceived the research idea, writing- original draft, data analysis, review, final approval and agreeing to the accuracy of the work. I.A. - data request, writing- original draft, data analysis, formatting of tables, review, final approval, and agreeing to the accuracy of the work. J.K.T. - conceptualisation, writing- original draft, data analysis, formatting of tables, compilation of paper, review, final proofreading and agreeing to the accuracy of the work.

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Data availability

The datasets used and/or analyzed during the current study available from the corresponding author on reasonable request.

Declarations

Ethics approval and consent to participate

The data used in this study were obtained from the 2019 Liberia Demographic and Health Survey (LDHS), with permission for data access granted through an online request submitted to http://www.dhsprogram.com. The researchers did not interact with respondents; hence, there was no need for ethical clearance. The data used were publicly available with no personal identifiers.

Consent for publication

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Competing interests

The authors declare no competing interests.

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