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Coexisting predictors for undernutrition indices among under-five children in West Africa: application of a multilevel multivariate ordinal logistic regression model

Abebew Aklog Asmare[1,2*], Awoke Seyoum Tegegne[1], Denekew Bitew Belay[1,3] and Yitateku Adugna Agmas[4,5]

Abstract

Background Due to its immediate and long-term implications for population health and socioeconomic advancement, children's nutritional status is especially crucial. It is the main reason for morbidity and mortality in children under five. Therefore, this study aimed to investigate predictors for under-nutrition indices among under-five children in West Africa.

Method The study was conducted in 14 countries in West Africa. A weighted total sample of 35,162 under-five children was included. Considering the impact of other predictors such as maternal, child, and socioeconomic variables, a multilevel multivariate partial proportional ordinal logistic regression model was conducted to analyze the relationship between stunting, wasting and underweight.

Result Among the participants in the study, approximately 27.7% were stunted, with 17.9% moderately stunted and 10.8% severely stunted. Additionally, about 18.6% (13.3% moderately and 5.3% severely) were underweight, and 9% (6.7% moderately and 2.3% severely) were wasted. More than half of the children (51.1%) were male, and 36.6% lived in urban areas. Compared to singleton children, a child with multiple birth types was 2.701, 3.740, and 1.777 times more likely to be stunted, underweight, and wasted, respectively.

Conclusion The findings in the current study revealed a direct correlation among underweight status, wasting, and stunting. Furthermore, even when ignoring the effects of other independent variables, underweight was found to serve as a composite measure of stunting and wasting when examining the link between these three indicators. The results identified several common predictors significantly associated with all three undernourishment indices. Therefore, governments and non-governmental organizations should prioritize public health interventions aimed at improving parental education and increasing antenatal care visits to enhance the nutritional status of under-five children. More attention should be given to improving healthcare delivery at health facilities and homes, promoting children's health education, and ensuring access to clean drinking water sources.

*Correspondence:
Abebew Aklog Asmare
aklog28@gmail.com

Full list of author information is available at the end of the article

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Keywords Under-five children, Multilevel multivariate partial proportional ordinal logistic regression, Stunting, Wasting, West Africa, Underweight

Introduction

The word "malnutrition" encompasses both overnutrition and undernutrition in individuals, posing barriers to optimal health [1, 2]. Among children under five, it stands as the primary cause of morbidity and mortality [3]. Although undernutrition rates are gradually declining globally, this decline rate is not uniform across all regions. Child malnutrition remains a significant challenge in middle- and low-income countries, particularly in Sub-Saharan Africa, where a substantial proportion of children experience chronic malnutrition [4]. Given its impact on population well-being and socioeconomic progress, children's nutritional status holds particular importance in both the short and long term of life. Early-life severe malnutrition often leads to impaired cognitive development, diminished academic performance, adverse maternal reproductive outcomes, reduced adult economic productivity, and increased strain on healthcare systems [5, 6]. Stunting, underweight, and wasting serve as the three anthropometric indicators of malnutrition, reflecting nutritional imbalances or deficiencies affecting the health status of children [7–10]. These indicators are widely acknowledged as markers of the severity of malnutrition in children [11]. In developing nations, malnutrition contributes to nearly half of all deaths among children under five [12].

In 2023, about half of all childhood deaths were attributed to undernutrition. During the same year, 12.7% of under-five children were underweight, 6.8% were wasted, and 22.3% were stunted [13]. Additionally, in 2022, there were 148.1 million under-five stunted children, with 52% residing in Asia and 43% in Africa [13]. Among the 45 million under-five children affected by wasting, 13.6 million (2.1%) were severely wasted, with over three-quarters residing in Asia and an additional 22% in Africa [13]. A more comprehensive analysis of under-nutrition distribution on the African continent reveals that stunting is more prevalent in Eastern Africa (30.6%) compared to Western Africa (30.0%), Northern Africa (23.5%), or Southern Africa (23.4%) [13].

In West Africa, several studies have been conducted on stunting, underweight, and wasting among under-five children. However, these studies have tried to identify predictors for undernutrition indicators in West African children and overlooked their interconnections [5, 14–18]. Some studies utilized multivariate binary logistic regression [19, 20], while others conducted multilevel multivariate binary logistic regression [12]. However, in such studies, binary logistic regression was conducted by collapsing undernutrition status levels into two categories [20]; others considered standard binary logistic regression, assuming no cluster heterogeneity among the study units [21, 22]. Therefore, multilevel multivariate ordinal logistic regression was conducted in this study, considered to offer a more nuanced understanding of the severity of undernutrition among under-five children. Hence, most research conducted previously lacked a large study area and didn't assess the interrelationships of predictors. Despite West Africa's diversity in culture, language, and other traits, clustering effects in which individuals within the same group have comparable outcomes are sometimes neglected. Children from the same country are more likely to have similar nutritional outcomes due to shared national characteristics in the setting of child malnutrition. Ignoring these impacts can result in skewed estimates that fail to account for both within- and between-country variability. This study closes this gap by treating each of the 14 West African countries as a cluster, representing the data's nested structure of children within homes and households within countries. This method compensates for unobserved country-level differences in healthcare systems, nutritional programs, economic situations, and cultural traditions, allowing for more precise estimates of individual and household-level factors impacting undernutrition.

As a result, this study is critical for understanding the simultaneous prevalence of stunting, wasting, and underweight in children, which are frequently investigated separately. The study uses a multilevel multivariate ordinal logistic regression approach to capture the shared and distinct determinants of these connected variables, resulting in a more nuanced and accurate analysis of child undernutrition. This is especially important in West Africa, where high rates of malnutrition remain due to socioeconomic inequality, food poverty, and poor healthcare access. The region-specific insights promote evidence-based initiatives that are in line with global targets like SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-Being). Methodologically, the study advances the field by demonstrating the effectiveness of multivariate modeling in public health research, promoting integrated analysis and policymaking, and encouraging future studies to use similarly comprehensive frameworks when addressing complex health challenges.

Method and participants

Study area

The current study was conducted in West Africa, which consists of diverse linguistic, cultural, and other characteristics. Hence, the current study includes 14 West

African nations, including Benin, Burkina Faso, Cote d'Ivoire, The Gambia, Ghana, Guinea, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, and Togo.

Data source and sampling method

This investigation utilized data from the Demographic and Health Survey (DHS), collected using a cross-sectional study approach. Specifically, focus on the Kids Record (KR) files, which provide detailed information on mothers and children. Given the hierarchical structure of the DHS data and the fact that children are nested within clusters, it is expected that children within the same cluster will exhibit greater similarity than children across the entire nation. The DHS survey employed a two-stage cluster sampling method that was stratified. Data collection was conducted through the measure of the DHS website, available at https://dhsprogram.com/Data/terms-of-use.cfm. For this analysis, a weighted total sample of 35,162 under-five children was utilized, representing a comprehensive dataset that provides valuable insights into the under-nutrition status and associated factors among children in the West African region.

Inclusion/exclusion criteria

The inclusion criteria for this study encompassed children under five who had full personal information and clinical symptoms. Children who were older than five years or who had incomplete information in the questionnaires were excluded from the analysis. This ensured that the study focused specifically on children within the target age group and with comprehensive data available for analysis.

Study variables and measurements

Response variables

In this study, three dependent variables, stunting, underweight, and wasting, were considered as under-nutrition indicators. After calculating the Z-score Z_i for each child, the under-nutrition indices were re-coded into ordinal variables as follows:

$$Stunted(0 = normal\ if\ HAZ \geq -2, 1 = \text{moderately stunted if} -3 \leq \text{HAZ} < -2 \text{ and } 2 = \text{severely stunted if HAZ} < -3)$$

$$Underweight\ (0 = normal\ if\ WAZ \geq -2,\ 1 = \text{moderately underweight if} -3 \leq \text{WAZ} < -2 \text{ and } 2 = \text{severely underweight if WAZ} < -3)$$

$$Wasted\ (0 = normal\ if\ WHZ \geq -2,\ 1 = \text{moderately wasted if} -3 \leq \text{WAZ} < -2 \text{ and } 2 = \text{severely wasted if WAZ} < -3)$$

The WHO's 2006 child growth standards were used to measure the resultant variables [23].

Explanatory variables

The choice of explanatory variables in this study is theoretically motivated and is supported by earlier research on the factors influencing children's nutritional status. When categorizing naturally continuous and discrete variables, previous studies are cited for guidance [12, 19, 20, 24–26] (Table 3).

Data analysis

An ordinal multilevel logistic regression model was conducted to identify significant predictors associated with indices of under-nutrition. Adjusted odds ratios (AOR) were calculated with a significance level set at $p \leq 0.05$ and a 95% confidence interval (CI).

In the present study, let $Y_{i1},\ Y_{i2},\ and\ Y_{i3}$ are the ordinal outcomes of stunting, underweight, and wasting of the ith under-five children, respectively. For ordinal outcome Y_{ij} and a vector of independent variables $\boldsymbol{x}$, multivariate proportional Odds Model is instrumental to model the ordinal dependent variables through defining the cumulative probabilities rather than the probability of an individual event. The multivariate proportional odds model calculates the probability of falling into a specific response variable range, considering the likelihood of both that event and every preceding event. The multivariate proportional odds model with the logit, or log-odds, of the first i^{th} cumulative probabilities is expressed as follows [27]:

$$logit\,[Y_{ji} \leq j/X_i] = \log\left[\frac{\pi_j(X_i)}{1-\pi_j(X_i)}\right] = logit\,(\pi_j) = \alpha_j - X_i'\beta,\ j = 1, \ldots, C-1,\ i = 1,2, \ldots, n \quad (1)$$

Generalized ordered logit model (GOLM)

The Generalized Ordered Logistic Model (GOLM), which considers the parallel lines assumption for each outcome category, allowing for different slope coefficients for each binary regression, was conducted [28].

Partial proportional odds model (PPOM)

In cases where the assumption of proportional odds is not fully met for all factors, a partially proportional odds

or non-proportional odds model can be utilized. The partial proportional odds model is employed when the proportional odds assumption does not hold for all factors [28]. This model allows for flexibility in capturing the varying effects of predictors on different levels of the response variable. The proportionate odds assumption can be applied to some covariates in this model; however, for variables in which the assumption is not met, a coefficient (γ) that is adjusted by the other covariates increases the effect associated with each ith cumulative logit [28]. Thus, the PPOM, which was used in this investigation is expressed as:

$$\log\left[\frac{pr\left(Y_{ji}\leq j/X_i\right)}{pr(Y_{ji}>j/X_i)}\right]=\alpha_j-\left(X'\beta-\tau\gamma_j\right),\ j=1,\ldots,C-1,\ i=1,2,\ldots,n \tag{2}$$

Where x is vector containing the full set of independent variables, τ is a vector of subset independent variables that violate the parallel line assumption, and γ_j the regression coefficients associated with τ. The expected probabilities of belonging to a certain category are defined by taking the exponential and rearranging the equation on both sides. The odds ratio is the preferred method used to measure the relationship between categorical variables in the logistic regression model [28]. It is defined as the proportion of odds:

$$OR_j=\frac{\pi_j\left(X_1\right)\Big/1-\pi_j\left(X_1\right)}{\pi_j\left(X_2\right)\Big/1-\pi_j\left(X_2\right)} \tag{3}$$

Multilevel multivariate logistic regression

Several studies have separately evaluated anthropometric indicators in under-five children, including underweight, stunting, and wasting, using binary logistic regression analysis to assess the impact of covariates on each of them [7, 26, 29–33]. However, conducting separate analyses does not account for the interconnections between the anthropometric markers. A multivariate ordinal logistic regression model was conducted to elucidate the correlation between estimates of covariate effects and anthropometric indices [20].

To assess the effects of variables on anthropometric measures in a region with a diverse population, such as West Africa, relying solely on a multivariate ordinal logistic regression model may not be adequate. Given the DHS data collected from children residing in various West African nations, there is a strong possibility of a clustering effect. The clustering effect can be evaluated using metrics such as the intra-class correlation coefficient (ICC) [34, 35] and the median odds ratio (MOR) [36]. The ICC can be calculated using the following formula:

$$ICC=\frac{\widehat{\sigma}_r^{\,2}}{\widehat{\sigma}^{\,2}+\widehat{\sigma}_r^{\,2}} \tag{4}$$

where $\widehat{\sigma}_r^{\,2}$ and $\widehat{\sigma}^{\,2}$ are the estimated cluster variance (regarding to country) and residual variance, respectively [34, 35]. The MOR is defined as: $MOR=exp\left[0.6745\sqrt{2\widehat{\sigma}_r^{\,2}}\right]$ [34, 37]. After preparing the data in SPSS 26, the statistical analysis was carried out using R software, VGAM, mvord, and the GLMER tools.

Model selection

The log likelihood of the ordinal logistic models was calculated to compare them, with the model having a greater log likelihood considered to be a better-fitting. When comparing models using the Akaike Information Criterion (AIC) and Bayes' Information Criterion (BIC), preference is given to models with the smallest absolute AIC and BIC statistics [38]. The model with the lowest AIC and BIC values is selected as the best model among a set of competing models.

Test of overall model fit

Before fitting a model, it is crucial to evaluate its appropriateness or goodness of fit. Assessing the model's forecasting performance can shed light on this aspect. The concordance proportion is a common metric used to evaluate or assess the predictive power of a multivariate logistic regression model. It measures the likelihood that the results and forecasts agree, or if the expected and actual outcomes match [39]. In this study, the concordance proportion was analyzed to determine how closely the projected model approximates the data.

Results

Baseline characteristics of the response variables

Among the participants, a weighted total of 18.6% (13.3% moderately and 5.3% severely) were underweight, 9% (6.7% moderately and 2.3% severely) were wasting, and 27.7% (17.9% moderately and 10.8% severely) were stunted (Table 1). The prevalence of underweight, wasting, and stunting varied across countries. Table 2 indicates that the highest prevalence of underweight, wasting, and stunting was observed in Niger (45.5%, 42.8%, and 22.0% (55.3%), respectively), while the lowest prevalence was found in Ghana (17.7%), Liberia (9.9%), and Togo (3.9%). The results showed that in (Table 3) 36.6% of the children are urban dwellers, more than half of the children (51.1%) were male, and nearly 30%

Table 1 Undernutrition outcomes of the sample ($n = 35,162$)

Outcome variables	Categories	Weighted frequency (%)
Stunting	Normal	25,043 (71.2)
	Moderately stunted	6308 (17.9)
	Severely stunted	3811 (10.8)
Underweight	Normal	28,611 (81.4)
	Moderately underweight	4679 (13.3)
	Severely underweight	1873 (5.3)
Wasted	Normal	32,020 (91.1)
	Moderately wasted	2346 (6.7)
	Severely wasted	797 (2.3)

(29.4%) of the children were between the ages of 12 and 23 months. 37.2% of homes have two children under the age of five, whereas the majority of households (52.2%) have five to nine family members (medium). 52.8% of spouses and 57.2% of mothers did not complete any formal schooling. On the other hand, 42.4% of the children came from households with a low wealth index, while 50.5% of the youngsters came from households with outdated restrooms. Of the children, 22.8% were anemic, and nearly 30% (30.7%) were born at home.

Tables 4 and 5 in the current study indicated that under-five children were affected by more than one of the three under-nutrition indicators. Therefore, it is imperative to approach the entire population of malnourished children with empathy and address their needs comprehensively. For instance, as illustrated, 1599 (4.55%) of the children experienced both moderate stunting and moderate underweight. Please refer to Tables 4 and 5.

The composite index of anthropometric failure (CIAF) was used to quantify the overall prevalence of markers of undernourishment [40]. According to the composite index of failure, approximately 35.91% of under-five children were diagnosed with malnutrition, whereas 64.09% of the children sampled in West Africa were not diagnosed with malnutrition. The findings indicate that 35.91% of under-five children were wasted, underweight, or stunted. This means that the region's overall child undernourishment rate was probably about 35.91% (Table 5).

Table 6 revealed that odds ratios (OR) were used to illustrate every potential pairwise dependency between the three anthropometric indices of underweight, wasting, and stunting. The odds ratios for stunting and underweight, stunting and wasting, and underweight and wasting are reported as 2.938, 1.657, and 2.431, respectively. These values deviate from unity, indicating that there is a relationship between the three anthropometric measures. Hence, a multivariate ordinal logistic model for each of the three responses was conducted to account for this relationship and to estimate the effects of predictors.

Table 7 presents a bivariable analysis of the correlation between predictors and each under-nutrition indicator. Except for the sex of the household head, vitamin A intake in the six months before the study, and fever in the two weeks before the survey, all predictors were associated with the three under-nutrition indicators (p-value less than 5%).

Parameter Estimation

Ordinal logistic regression models

Proportional odds model were rejected following the Brant test, which revealed a violation of the parallel regression assumption (Chi-Square = 97.72, p-value = 0.000). Instead, both a partial proportional

Table 2 Frequency distribution of undernutrition outcomes in West Africa

Country name	DHS Year	Total frequency (%)	Stunting		Underweight		Wasting	
			Moderately stunted (%)	Severely stunted (%)	Moderately underweight (%)	Severely underweight (%)	Moderately wasted (%)	Severely wasted (%)
Benin	2017/18	5174 (14.7)	1115 (21.6)	567 (11.0)	694 (13.4)	194 (3.7)	217 (4.2)	42 (0.8)
Burkina-Faso	2021	2775 (7.9)	417 (15.0)	155 (5.6)	384 (13.8)	124 (4.5)	295 (10.6)	88 (3.2)
Cote d'Ivoire	2021	1898 (5.4)	262 (13.8)	133 (7.0)	196 (10.3)	76 (4.0)	150 (7.9)	60 (3.2)
Gambia	2019/20	1948 (5.5)	267 (13.7)	73 (3.7)	169 (8.7)	46 (2.4)	82 (4.2)	13 (0.7)
Ghana	2014	1654 (4.7)	198 (12.0)	61 (3.7)	150 (9.1)	26 (1.6)	81 (4.9)	14 (0.8)
Guinea	2018	1998 (5.7)	364 (18.2)	275 (13.8)	234 (11.7)	102 (5.1)	120 (6.0)	77 (3.9)
Liberia	2019/20	1005 (2.9)	181 (18.0)	66 (6.6)	77 (7.7)	22 (2.2)	36 (3.6)	3 (0.3)
Mali	2018	2427 (6.9)	395 (16.3)	240 (9.9)	337 (13.9)	149 (6.1)	181 (7.5)	80 (3.3)
Mauritania	2019	1971 (5.6)	294 (14.9)	151 (77.7)	232 (11.8)	70 (3.6)	107 (5.4)	18 (0.9)
Niger	2012	2237 (6.4)	526 (23.5)	515 (23.0)	610 (27.3)	347 (15.5)	328 (14.7)	163 (7.3)
Nigeria	2018	6717 (19.1)	1309 (19.5)	1069 (15.9)	959 (14.3)	529 (7.9)	411 (6.1)	164 (2.4)
Senegal	2019	1499 (4.3)	255 (17.0)	176 (11.7)	204 (13.6)	68 (4.5)	119 (7.9)	33 (2.2)
Sera Leone	2019	2095 (6.0)	408 (19.5)	180 (8.6)	205 (9.8)	55 (2.6)	109 (5.2)	15 (0.7)
Togo	2014	1763 (5.0)	316 (17.9)	149 (8.5)	227 (12.9)	65 (3.7)	108 (6.1)	28 (1.6)

Table 3 Independent variable description and frequency distribution in West Africa

Variables	Categories	Weighted frequency (%)
Age of mother at first birth	Less than 20	1755 (5.0)
	20 to 34	23,730 (67.5)
	35 and more	9677 (27.5)
Type of place of residence	Urban	12,863 (36.6)
	Rural	22,300 (63.4)
Mother education level	No education	20,104 (57.2)
	Primary education	6356 (18.1)
	Secondary education	7468 (21.2)
	Higher education	1234 (3.5)
Source of drinking water	Unimproved	9176 (26.1)
	Improved	25,986 (73.9)
Type of toilet facility	Unimproved	17,758 (50.5)
	Improved	17,404 (49.5)
Family size	Small (1–4)	8094 (23.0)
	Medium (5–9)	18,371 (52.2)
	Large (10 and more)	8697 (24.7)
Number of under five children	Only one child	11,638 (33.1)
	Two children	13,075 (37.2)
	3 and more children	10,449 (29.7)
Sex of household head	Male	30,082 (85.6)
	Female	5081 (14.4)
Wealth index	Poor	14,925 (42.4)
	Middle	7203 (20.5)
	Rich	13,034 (37.1)
Body mass index of mother	Thin	2974 (8.5)
	Normal	21,820 (62.1)
	Overweight	6897 (19.6)
	Obese	3471 (9.9)
Husband education level	No education	18,569 (52.8)
	Primary education	5124 (14.6)
	Secondary education	8692 (24.7)
	Higher education	2778 (7.9)
Mother current working status	No	12,767 (36.3)
	Yes	22,395 (63.7)
Birth type of child	Single birth	34,333 (97.6)
	Multiple birth	829 (2.4)
Sex of child	Male	17,958 (51.1)
	Female	17,205 (48.9)
Current age of child	0 to 11 months	10,118 (28.8)
	12 to 23 months	10,336 (29.4)
	24 to 35 months	7599 (21.6)
	36 to 47 months	4176 (11.9)
	48 to 59 months	2934 (8.3)
Number of antenatal visits during pregnancy	Less than 4 visits	13,373 (38.0)
	4 and more visits	21,789 (62.0)
Place of delivery	Home	10,806 (30.7)
	Health facility	24,357 (69.3)
Size of child at birth	Small	5596 (15.9)
	Average	17,472 (49.7)
	Large	12,095 (34.4)
Diarrhea	No	29,383 (83.6)
	Yes	5780 (16.4)

Table 3 (continued)

Variables	Categories	Weighted frequency (%)
Fever	No	27,246 (77.5)
	Yes	7916 (22.5)
Cough	No	28,955 (82.3)
	Yes	6207 (17.7)
Vitamin A	No	16,430 (46.7)
	Yes	18,732 (53.3)
Child anemia level	Not anemic	8018 (22.8)
	Anemic	27,144 (77.2)

Table 4 Simultaneous frequency distribution of stunting, underweight and wasting

				Underweight			Total
				Normal	**Moderately underweight**	**Severely underweight**	
Wasting	Normal	**Stunting**	Normal	22,536	540	0	23,076
			Moderately stunted	4074	1599	33	5706
			Severely stunted	1120	1387	730	3237
	Moderately Wasted	**Stunting**	Normal	726	744	19	1489
			Moderately stunted	0	224	248	472
			Severely stunted	0	3	382	385
	Severely wasted	**Stunting**	Normal	154	182	142	478
			Moderately stunted	0	0	130	130
			Severely stunted	0	0	189	189
Total				28,610	4679	1873	35,162

Table 5 Cross-classification of undernutrition indicators and resultant frequency distribution

Undernourished indicators	Weighted frequency (%)
Non– undernourished	22,536 (64.09)
Moderately stunted only	4074 (11.59)
Severely stunted only	1120 (3.19)
Moderately underweight only	540 (1.54)
Severely underweight only	0 (0.0)
Moderately wasted only	726 (2.06)
Severely wasted only	154 (0.44)
Moderately stunted and moderately underweight	1599 (4.55)
Moderately stunted and severely underweight	33 (0.09)
Severely stunted and moderately underweight	1387 (3.92)
Severely stunted and severely underweight	730 (2.08)
Moderately stunted and moderately wasted	0 (0.0)
Moderately stunted and severely wasted	0 (0.0)
Severely stunted and moderately wasted	0 (0.0)
Severely stunted and severely wasted	0 (0.0)
Moderately underweight and moderately wasted	744 (2.12)
Moderately underweight and severely wasted	182 (0.52)
Severely underweight and moderately wasted	19 (0.05)
Severely underweight and severely wasted	142 (0.40)
Moderately stunted, moderately underweight and moderately wasted	224 (0.64)
Moderately stunted, moderately underweight and severely wasted	0 (0.0)
Moderately stunted, severely underweight and moderately wasted	248 (0.71)
Moderately stunted, severely underweight and severely wasted	130 (0.37)
Severely stunted, moderately underweight and moderately wasted	3 (0.01)
Severely stunted, moderately underweight and severely wasted	0 (0.0)
Severely stunted, severely underweight and moderately wasted	382 (1.09)
Severely stunted, severely underweight and severely wasted	189 (0.54)

Table 6 Pairwise dependency between undernutrition indicators using odds ratio (OR)

	Stunting	Underweight
	OR (95%CI)	OR (95%CI)
Wasting	1.657 (1.238, 1.976)	2.431 (2.017, 2.874)
Underweight	2.938 (2.357, 3.483)	

odds model and a generalized ordered logit model were applied to the data. The PPOM model demonstrated in Table 8 indicates that a lower AIC and BIC, indicating greater parsimony and a better fit to the data. Consequently, parameter estimates of the PPOM were examined and discussed for the relevant predictors at a 5% significance level. The PPOM was then utilized to identify significant drivers of under-nutrition indicators.

Results of partial proportional odds model

Table 9 displays two result panels. In the first panel, normal categories are compared with underweight, wasting, and moderately and severely stunted individuals. Unlike the other two under-nutrition categories, the signals of coefficients in the first panel indicated the likelihood of the child's nourishment. In the second panel, the severely stunted, underweight, and wasted categories are contrasted with the normal and moderately stunted, underweight, and wasted categories. Therefore, higher category values on the predictor increase the likelihood that the respondent will be in a higher category than the current one, whereas higher category values on the predictor increase the likelihood that the respondent will be in the current or a lower category. Positive coefficients suggest this relationship.

Every predictor in the partial proportional odds model violated the parallel line assumption. Consequently, the model allows the coefficients of these variables to differ between the two equations.

Random effect model

The calculated Intra-class Correlation Coefficients (ICCs) for stunting, underweight, and wasting were 57.34%, 54.29%, and 56.61%, respectively, indicating a high value. This strongly suggests the presence of a clustering effect and between-group variability that would benefit from considering the cluster effect due to country. A high

Table 7 Bivariate analysis of undernutrition indices with the predictors

Predictors	Stunting		Underweight		Wasting	
	Chi– square	*P*– value	Chi– square	*P*– value	Chi– square	*P*–value
Age of mother at first birth	15.754	0.003	19.230	0.001	11.622	0.020
Types of place of residence	631.664	0.000	452.820	0.000	89.354	0.000
Mother education level	955.768	0.000	637.062	0.000	137.323	0.000
Source of drinking water	380.915	0.000	152.215	0.000	4.103	0.129
Types of toilet facility	598.862	0.000	377.257	0.000	65.021	0.000
Family size	49.624	0.000	38.808	0.000	10.032	0.040
Number of under five children	90.383	0.000	127.432	0.000	64.542	0.000
Sex of household head	3.217	0.200	2.666	0.264	16.122	0.000
Wealth index	818.554	0.000	437.291	0.000	48.538	0.000
Body mass index of mother	633.682	0.000	1018.669	0.000	464.851	0.000
Husband education level	643.462	0.000	542.915	0.000	144.153	0.000
Mother current working status	42.281	0.000	146.130	0.000	123.560	0.000
Birth types of child	183.245	0.000	202.978	0.000	19.921	0.000
Sex of child	109.251	0.000	48.832	0.000	43.819	0.000
Current age of child	1324.361	0.000	251.467	0.000	351.556	0.000
Number of antenatal visits during pregnancy	395.107	0.000	398.895	0.000	157.350	0.000
Place of delivery	1037.539	0.000	869.868	0.000	170.234	0.000
Size of child at birth	271.601	0.000	669.190	0.000	205.873	0.000
Diarrhea	55.902	0.000	184.542	0.000	89.299	0.000
Fever	38.729	0.000	97.860	0.000	64.222	0.000
Cough	4.849	0.089	1.350	0.509	0.905	0.636
Vitamin A	27.688	0.000	17.367	0.000	5.090	0.078
Child anemia level	141.964	0.000	147.143	0.000	43.977	0.000

Table 8 Log-likelihood and likelihood ratio estimates

Model	Observations	LL (Null)	LL (Model)	DF	LR χ^2	*P*– value	AIC	BIC
GOLM	35,788	-21295.07	-19766.98	76	3036.18	0.000	39705.96	40350.85
PPOM	35,788	-12565.74	-11904.51	46	1322.46	0.000	23961.02	24605.91

Table 9 Maximum likelihood estimates of partial proportional odds model

Predicators	Stunting		Underweight		Wasting	
	AOR (95% CI)	*P*– value	AOR (95% CI)	*P*– value	AOR (95% CI)	*P*–value
Normal versus (moderately and severely stunting, underweight and wasting)						
Intercept	0.601 (0.502, 0.720)	0.000	0.788 (0.645, 0.963)	0.020	0.491 (0.378, 0.638)	0.000
Age of mother at first birth						
Less than 20	Ref.		Ref.		Ref.	
20 to 34	0.795 (0.712, 0.888)	0.000	0.950 (0.839, 1.075)	0.431	0.964 (0.943, 1.306)	0.209
35 and more	0.744 (0.660, 0.838)	0.000	0.934 (0.817, 1.068)	0.322	0.967 (0.963, 1.374)	0.122
Type of place of residence						
Urban	Ref.		Ref.		Ref.	
Rural	1.069 (1.002, 1.140)	0.043	1.107 (1.027, 1.194)	0.008	1.061 (0.959, 1.173)	0.251
Mother education level						
No education	Ref.		Ref.		Ref.	
Primary education	0.841 (0.785, 0.901)	0.000	0.741 (0.683, 0.805)	0.000	0.805 (0.709, 0.914)	0.000
Secondary education	0.708 (0.653, 0.768)	0.000	0.716 (0.650, 0.787)	0.000	0.814 (0.728, 0.910)	0.001
Higher education	0.568 (0.461, 0.701)	0.000	0.680 (0.531, 0.872)	0.002	0.846 (0.626, 1.143)	0.726
Source of drinking water						
Unimproved	Ref.		Ref.		Ref.	
Improved	0.886 (0.837, 0.937)	0.000	0.951 (0.892, 1.014)	0.123	1.074 (0.982, 1.173)	0.117
Type of toilet facility						
Unimproved	Ref.		Ref.		Ref.	
Improved	0.897 (0.848, 0.950)	0.000	0.899 (0.842, 0.959)	0.001	0.884 (0.810, 0.966)	0006
Family size						
Small (1–4)	0.934 (0.853, 1.023)	0.141	0.942 (0.849, 1.046)	0.266	0.974 (0.882, 1.076)	0.607
Medium (5–9)	0.935 (0.874, 1.001)	0.052	0.969 (0.895, 1.049)	0.436	0.993 (0.879, 1.122)	0.911
Large (10 and more)	Ref.		Ref.		Ref.	
Number of under five						
Only one child	Ref.		Ref.		Ref.	
Two children	1.086 (1.021, 1.156)	0.009	1.041 (0.968, 1.120)	0.274	0.973 (0.970, 1.202)	0.163
3 and more children	1.148 (1.060, 1.242)	0.001	1.098 (1.002, 1.202)	0.044	0.977 (0.848, 1.125)	0.745
Sex of household head						
Male	Ref.		Ref.		Ref.	
Female	1.004 (0.935, 1.078)	0.910	1.002 (0.922, 1.089)	0.961	1.012 (0.845, 1.060)	0.339
Wealth index						
Poor	Ref.		Ref.		Ref.	
Middle	0.930 (0.871, 0.993)	0.031	1.029 (0.954, 1.109)	0.463	0.995 (0.989, 1.215)	0.082
Rich	0.848 (0.786, 0.915)	0.000	1.104 (1.012, 1.204)	0.025	0.997 (0.953, 1.122)	0.091
Body mass index of mother						
Thin	Ref.		Ref.		Ref.	
Normal	0.828 (0.763, 0.899)	0.000	0.526 (0.484, 0.573)	0.000	0.497 (0.447, 0.553)	0.000

Table 9 (continued)

Predicators	Stunting		Underweight		Wasting	
	AOR (95% CI)	*P*– value	AOR (95% CI)	*P*– value	AOR (95% CI)	*P*–value
Overweight	0.633 (0.573, 0.699)	0.000	0.347 (0.311, 0.388)	0.000	0.401 (0.349, 0.462)	0.000
Obese	0.570 (0.460, 0.589)	0.000	0.276 (0.239, 0.320)	0.000	0.288 (0.237, 0.351)	0.000
Husband education level						
No education	Ref.		Ref.		Ref.	
Primary education	0.996 (0.925, 1.071)	0.907	0.962 (0.883, 1.047)	0.371	0.864 (0.768, 0.971)	0.014
Secondary education	0.932 (0.867, 1.001)	0.055	0.873 (0.801, 0.950)	0.002	0.794 (0.707, 0.892)	0.000
Higher education	0.827 (0.727, 0.941)	0.004	0.735 (0.629, 0.859)	0.000	0.689 (0.571, 0.855)	0.001
Mother current working status						
No	Ref.		Ref.		Ref.	
Yes	0.974 (0.925, 1.026)	0.317	0.864 (0.815, 0.916)	0.000	0.821 (0.759, 0.887)	0.000
Birth type of child						
Single birth	Ref.		Ref.		Ref.	
Multiple birth	2.711 (2.339, 3.142)	0.000	2.582 (2.213, 3.012)	0.000	1.748 (1.419, 2.152)	0.000
Current age of child in month						
0 to 11 months	Ref.		Ref.		Ref.	
12 to 23 months	2.703 (2.520, 2.900)	0.000	1.599 (1.482, 1.725)	0.000	1.514 (1.158, 1.981)	0.000
24 to 35 months	3.871 (3.593, 4.170)	0.000	1.730 (1.593, 1.878)	0.000	1.330 (1.110, 1.595)	0.000
36 to 47 months	3.706 (3.389, 4.053)	0.000	1.531 (1.380, 1.698)	0.000	1.290 (0.858, 1.941)	0.220
48 to 59 months	2.884 (2.601, 3.198)	0.000	1.462 (1.295, 1.650)	0.000	1.112 (0.856, 1.441)	0.429
Size of child at birth						
Small	Ref.		Ref.		Ref.	
Average	0.748 (0.700, 0.800)	0.000	0.633 (0.589, 0.680)	0.000	0.715 (0.649, 0.787)	0.000
Large	0.602 (0.560, 0.648)	0.000	0.444 (0.409, 0.481)	0.000	0.554 (0.497, 0.617)	0.000
Sex of child						
Male	Ref.		Ref.		Ref.	
Female	0.749 (0.714, 0.786)	0.000	0.797 (0.754, 0.843)	0.000	0.733 (0.680, 0.791)	0.000
Number of antenatal visits						
Less than 4 visits	Ref.		Ref.		Ref.	
4 and more visits	0.880 (0.835, 0.928)	0.000	0.847 (0.796, 0.900)	0.000	0.806 (0.743, 0.874)	0.000
Place of delivery						
Home	Ref.		Ref.		Ref.	
Health facility	0.707 (0.668, 0.747)	0.000	0.683 (0.641, 0.727)	0.000	0.813 (0.743, 0.885)	0.000
Diarrhea						
No	Ref.		Ref.		Ref.	
Yes	1.142 (1.069, 1.220)	0.000	1.336 (1.243, 1.437)	0.000	1.195 (1.086, 1.316)	0.000
Fever						
No	Ref.		Ref.		Ref.	
Yes	1.109 (1.042, 1.180)	0.001	1.201 (1.120, 1.288)	0.000	1.292 (1.177, 1.417)	0.000

Table 9 (continued)

Predicators	**Stunting**		**Underweight**		**Wasting**	
	AOR (95% CI)	***P*– value**	**AOR (95% CI)**	***P*– value**	**AOR (95% CI)**	***P*–value**
Cough						
No	0.910 (0.850, 0.975)	0.007	0.970 (0.898, 1.049)	0.444	0.950 (0.856, 1.054)	0.332
Yes	Ref.		Ref.		Ref.	
Vitamin A						
No	0.956 (0.910, 1.005)	0.076	0.987 (0.970, 1.089)	0.350	0.924 (0.985, 1.180)	0.078
Yes	Ref.		Ref.		Ref.	
Child anemia level						
Not anemic	Ref.		Ref.		Ref.	
Anemic	1.348 (1.267, 1.434)	0.000	1.250 (1.161, 1.346)	0.000	1.092 (1.011, 1.179)	0.025
(Normal and moderately stunting, underweight and wasting) versus severely stunting, underweight and wasting						
Intercept	0.164 (0.127, 0.211)	0.000	0.272 (0.197, 0.377)	0.000	0.192 (0.120, 0.308)	0.000
Age of mother at first birth						
Less than 20	Ref.		Ref.		Ref.	
20 to 34	0.792 (0.679, 0.924)	0.000	0.894 (0.734, 1.088)	0.263	0.992 (0.806, 1.433)	0.644
35 and more	0.770 (0.652, 0.909)	0.000	0.908 (0.732, 1.126)	0.379	0.993 (0.759, 1.440)	0.786
Type of place of residence						
Urban	Ref.		Ref.		Ref.	
Rural	1.175 (1.066, 1.294)	0.000	1.181 (1.030, 1.355)	0.018	1.134 (0.753, 1.109)	0.362
Mother education level						
No education	Ref.		Ref.		Ref.	
Primary education	0.734 (0.662, 0.814)	0.000	0.722 (0.622, 0.838)	0.000	0.707 (0.567, 0.881)	0.002
Secondary education	0.582 (0.511, 0.663)	0.000	0.665 (0.556, 0.796)	0.000	0.688 (0.537, 0.881)	0.003
Higher education	0.482 (0.326, 0.714)	0.000	0.784 (0.491, 1.253)	0.309	0.733 (0.394, 1.362)	0.326
Source of drinking water						
Unimproved	Ref.		Ref.		Ref.	
Improved	0.874 (0.810, 0.944)	0.001	0.945 (0.851, 1.049)	0.288	1.129 (0.959, 1.329)	0.146
Type of toilet facility						
Unimproved	Ref.		Ref.		Ref.	
Improved	0.919 (0.848, 0.997)	0.041	0.819 (0.732, 0.915)	0.000	0.865 (0.732, 1.022)	0.089
Family size						
Small (1–4)	0.925 (0.813, 1.054)	0.242	0.863 (0.721, 1.034)	0.109	1.114 (0.911, 1.360)	0.293
Medium (5–9)	0.943 (0.854, 1.042)	0.249	0.954 (0.831, 1.123)	0.504	0.886 (0.680, 1.155)	0.372
Large (10 and more)	Ref.					
Number of under five children						
Only one child	Ref.		Ref.		Ref.	
Two children	1.072 (0.979, 1.173)	0.132	1.013 (0.867, 1.123)	0.858	0.922 (0.767, 1.110)	0.394
3 and more children	1.192 (1.066, 1.332)	0.002	1.113 (0.953, 1.301)	0.176	0.872 (0.695, 1.094)	0.235
Sex of household head						

Table 9 (continued)

Predicators	Stunting		Underweight		Wasting	
	AOR (95% CI)	***P*– value**	**AOR (95% CI)**	***P*– value**	**AOR (95% CI)**	***P*–value**
Male	Ref.		Ref.		Ref.	
Female	1.033 (0.930, 1.147)	0.544	1.012 (0.873, 1.039)	0.148	1.022 (1.002, 1.543)	0.006
Wealth index						
Poor	Ref.		Ref.		Ref.	
Middle	0.979 (0.892, 1.074)	0.655	0.978 (0.891, 1.193)	0.431	0.993 (0.981, 1.454)	0.065
Rich	0.959 (0.860, 1.069)	0.445	0.983 (0.874, 1.414)	0.462	0.972 (0.961, 1.569)	0.089
Body mass index of mother						
Thin	Ref.		Ref.		Ref.	
Normal	0.784 (0.704, 0.874)	0.000	0.499 (0.440, 0.565)	0.000	0.565 (0.467, 0.684)	0.000
Overweight	0.592 (0.515, 0.679)	0.000	0.333 (0.277, 0.399)	0.000	0.483 (0.374, 0.624)	0.000
Obese	0.515 (0.427, 0.620)	0.000	0.232 (0.175, 0.309)	0.000	0.318 (0.216, 0.467)	0.000
Husband education level						
No education	Ref.		Ref.		Ref.	
Primary education	0.991 (0.930, 1.147)	0.545	0.855 (0.735, 0.996)	0.044	0.743 (0.592, 0.934)	0.011
Secondary education	0.921 (0.827, 1.026)	0.137	0.842 (0.723, 0.982)	0.028	0.725 (0.579, 0.907)	0.005
Higher education	0.791 (0.639, 0.978)	0.031	0.765 (0.571, 1.023)	0.071	0.318 (0.216, 0.467)	0.014
Mother current working status						
No	Ref.		Ref.		Ref.	
Yes	0.898 (0.835, 0.965)	0.004	0.750 (0.680, 0.827)	0.000	0.678 (0.588, 0.783)	0.000
Birth type of child						
Single birth	Ref.		Ref.		Ref.	
Multiple birth	2.701 (2.254, 3.236)	0.000	3.740 (3.034, 4.608)	0.000	1.777 (1.218, 2.590)	0.003
Current age of child						
0 to 11 months	Ref.		Ref.		Ref.	
12 to 23 months	2.713 (2.427, 3.033)	0.000	1.368 (1.207, 1.551)	0.000	1.792 (1.408, 2.281)	0.000
24 to 35 months	4.385 (3.916, 4.907)	0.000	1.504 (1.314, 1.722)	0.000	1.267 (1.089, 1.475)	0.000
36 to 47 months	4.112 (3.606, 4.690)	0.000	1.187 (0.991, 1.422)	0.063	1.344 (0.447, 4.046)	0.596
48 to 59 months	2.990 (2.553, 3.498)	0.000	1.112 (0.847, 1.183)	0.607	1.101 (0.917, 1.320)	0.302
Size of child at birth						
Small	Ref.		Ref.		Ref.	
Average	0.739 (0.675, 0.810)	0.000	0.588 (0.525, 0.659)	0.000	0.672 (0.566, 0.798)	0.000
Large	0.644 (0.583, 0.712)	0.000	0.451 (0.395, 0.515)	0.000	0.503 (0.413, 0.613)	0.000
Sex of child						
Male	Ref.		Ref.		Ref.	
Female	0.728 (0.680, 0.781)	0.000	0.704 (0.640, 0.775)	0.000	0.684 (0.594, 0.787)	0.000
Number of antenatal visits						
Less than 4 visits	Ref.		Ref.		Ref.	
4 and more visits	0.810 (0.752, 0.873)	0.000	0.769 (0.694, 0.853)	0.000	0.801 (0.689, 0.932)	0.000

Table 9 (continued)

Predicators	Stunting		Underweight		Wasting	
	AOR (95% CI)	***P*– value**	**AOR (95% CI)**	***P*– value**	**AOR (95% CI)**	***P*–value**
Place of delivery						
Home	Ref.		Ref.		Ref.	
Health facility	0.594 (0.550, 0.642)	0.000	0.551 (0.495, 0.613)	0.000	0.640 (0.546, 0.750)	0.000
Diarrhea						
No	Ref.		Ref.		Ref.	
Yes	1.125 (1.027, 1.233)	0.000	1.219 (1.082, 1.374)	0.001	1.171 (0.980, 1.399)	0.081
Fever						
No	Ref.		Ref.		Ref.	
Yes	1.146 (1.051, 1.250)	0.000	1.272 (1.134, 1.427)	0.000	1.330 (1.119, 1.582)	0.001
Cough						
No	0.943 (0.856, 1.040)	0.240	0.993 (0.891, 1.165)	0.706	0.957 (0.788, 1.161)	0.656
Yes	Ref.		Ref.		Ref.	
Vitamin A						
No	0.895 (0.835, 0.960)	0.002	0.976 (0.845, 1.165)	0.166	0.976 (0.763, 0.994)	0.022
Yes	Ref.		Ref.		Ref.	
Child anemia level						
Not anemic	Ref.		Ref.		Ref.	
Anemic	1.495 (1.361, 1.643)	0.000	1.463 (1.274, 1.678)	0.000	1.036 (0.852, 1.260)	0.720
Random effect						
Variance	2.672	0.000	2.349	0.000	2.451	0.000
ICC%	57.34		54.29		56.61	
Dependency		**OR (95%CI)**		**P-value**		
Stunting and underweight		2.704 (2.503, 2.897)		0.000		
Stunting and wasting		1.192 (1.083, 1.312)		0.007		
Underweight and wasting		2.231 (1.969, 2.916)		0.000		

ICC indicates a high degree of similarity among children from the same country who have under-nutrition indicators. On the other hand, the estimated clustering variance on stunting $\left(\sigma_{rs}^{2}\right)$, underweight $\left(\sigma_{ru}^{2}\right)$, and wasting $\left(\sigma_{rw}^{2}\right)$, found to be significant (p–value 0.05) in the model indicates that there is a country effect in the model. Stunting (MOR = 1.593), underweight (MOR = 1.492), and wasting (MOR = 1.515) have different MOR values. This indicates that there was a significant clustering variation. Since the standard model is unable to exclude the cluster effect due to the nation, a multilevel multivariate ordinal logistic regression model was used (see Table 9).

Fixed effect model

The estimated odds of being moderately and severely stunted for under-five children whose mothers are aged between 20 and 34 years, and those whose mothers are aged above 35 years, were reduced by 20.5% and 25.6%, respectively, compared to under-five children whose mothers are younger than 20 years, given other factors constant.

The risk of being moderately or severely stunted for under-five children with mothers who had primary, secondary, or higher education were 0.841, 0.708, and 0.568 times higher, respectively, as compared to illiterate mothers. Compared to under-five children with mothers who had primary, secondary and higher education with uneducated mothers, the expected risk of being underweight for under-five children whose mothers had primary, secondary and higher education were: 0.741 (AOR = 0.741, 95% CI: 0.683–0.805), 0.716 (AOR = 0.716, 95% CI: 0.650–0.787), and 0.680 (AOR = 0.680, 95% CI: 0.531–0.872), times than illiterate mothers respectively.

The risks of being moderately and severely stunted, underweight, and wasted for under-five children whose house holds used improved toilet facilities were 0.897, 0.899, and 0.884 times higher, respectively, compared to under-five children whose households used unimproved toilet facilities. Compared to single births, multiple births were 2.711 (AOR = 2.711, 95% CI: 2.339–3.142), 2.582 (AOR = 2.582, 95% CI: 2.213–3.012), and 1.748 (AOR = 1.748, 95% CI: 1.419–2.152) times more likely to be moderately or severely stunted, underweight, and wasted, respectively.

The odds of being severely stunted for children in the age groups of 12–23 months, 24–35 months, 36–47 months, and 48–59 months were 2.713 (AOR = 2.713, 95% CI: 2.427–3.033), 4.385 (AOR = 4.385, 95% CI: 3.916–4.907), 4.112 (AOR = 4.112, 95% CI: 3.606–4.690), and 2.990 (AOR = 2.990, 95% CI: 2.553–3.498) times higher, respectively, compared to the odds of being severely stunted for children less than 12 months old.

The risk of being severely stunted for a child with an average or large birth size was 0.739 (AOR = 0.739, 95% CI: 0.675–0.810) and 0.644 (AOR = 0.644, 95% CI: 0.583–0.712) times, respectively, compared to the odds of being severely stunted for a child with a small birth size. The risk of being severely stunted, underweight, and wasted for female children was 0.728, 0.704, and 0.684 times, respectively, compared to the risk for male children.

The estimated odds of being stunted, underweight, and wasted for children with fever were 1.146 (AOR = 1.146, 95% CI: 1.051–1.250), 1.272 (AOR = 1.272, 95% CI: 1.134–1.427), and 1.330 (AOR = 1.330, 95% CI: 1.119–1.582) respectively times that of under-five children without fever.

The concordant and discordant indices were computed using a multilevel multivariate ordinal logistic regression model to estimate undernourishment indicators, and the result indicates that about 83.7% of the participants under study exhibited under-nutrition indicators such as stunting, underweight, and wasting. Hence, the concordant index was extremely high, demonstrating how well the model fit the data and was able to explain the relationship between the markers.

Discussion

The impacts of the independent variables were assessed using data from a recent demographic health survey in Western Africa. The model aimed to estimate the clustering effect by country and evaluate the relationship between underweight, wasting, and stunting. Using countries as clusters specifically, the 14 West African countries help to account for commonalities among children within the same country due to shared socioeconomic, cultural, health, and environmental characteristics. This clustering approach accounts for intra-country correlation, enhances statistical inference accuracy, and enables the calculation of country-level variation in underweight, wasting, and stunting. It also helps to build more context-specific policies by distinguishing between individual- and country-level influences on child nutrition outcomes. The findings revealed a direct correlation among underweight, wasting, and stunting. Furthermore, examining the link between the three indicators, underweight serves as a composite measure of stunting and wasting. This conclusion is supported by previous research conducted in Ethiopia, Nigeria, the Gambia, and East Africa [12, 19, 20, 25]. A significant correlation exists among underweight and wasting, stunting and underweight, and underweight and wasting. These findings align with previous studies [12, 19, 20, 25].

The prevalence of underweight, wasting, and stunting in this study was 9% (6.7% moderately wasted and

2.3% severely wasted), 18.6% (13.3% moderately underweight and 5.3% severely underweight), and 29.7% (18.9% moderately stunted and 10.8% severely stunted), respectively. While the prevalence of stunting and underweight was lower than that reported in studies from Nigeria and Ethiopia [19, 25], it was lower than the prevalence reported in a study from Gambia [20]. However, the prevalence of wasting was lower than the research findings in Ethiopia and higher than the prevalence reported in studies from East Africa, Gambia, and Nigeria [12, 19, 20]. The potential reason for this might be severe weather conditions, droughts, and food shortages, coupled with limited access to land for cultivation [41]. These dynamics severely impede the progress of child nutrition, nutrition security, and agricultural efficiency in West Africa.

Compared to under-five children whose parents with elementary, secondary, and higher education with uneducated ones, under-five children whose parents, uneducated are more likely to experience wasting, stunting, and underweight conditions. This finding aligns with several studies [25, 42] on malnutrition in children under five.

In line with prior research [43, 44], this study reveals unlikelihood of stunting, wasting, and underweight in children from households using improved toilet facilities. This phenomenon can be attributed to the influence of various sanitation practices and the presence of unimproved toilet facilities on children's nutritional well-being [45, 46]. A substandard sanitation system coupled with outdated toilet facilities may increase the vulnerability of children to infections, consequently leading to morbidity [44].

According to this study, children born to mothers with a normal weight or overweight status are less likely to suffer from malnutrition compared to children born to underweight mothers. It is hypothesized that maternal malnutrition could contribute to inadequate breast milk production, thereby affecting the child's nutritional status [47]. Previous studies conducted in Bangladesh [48], Nigeria [19], and Gambia [20] have also established a similar association between maternal body mass index and stunting and underweight in offspring. Additionally, twins are at a higher risk of malnutrition compared to single-born children due to the challenges associated with caring for two infants simultaneously. This finding is consistent with prior research [19, 47], suggesting a correlation between twin births and underweight, stunting, and wasting, potentially due to the increased care giving demands on the mother [48].

As age of under-five children increases, the likelihood of experiencing all three types of under-nutrition also increases and this result is aligned with one of the previous studies [49, 50]. Hence, older children may also be at a higher risk of experiencing all three nutritional disorders due to prolonged periods of poor nutritional habits or under-nutrition [49, 50]. These results suggest that the complementary foods provided to children during their development may be insufficient.

According to this study, children who were small at birth were more likely to experience stunting, wasting, and being underweight compared to children who were average or large at birth, which aligns with findings from previous studies [3, 51]. This increased risk among small babies may be attributed to their heightened susceptibility to infections, particularly diarrhea and lower respiratory infections like pneumonia and otitis media. Additionally, they are at a higher risk of complications such as sleep apnea, anemia, chronic lung disorders, fatigue, and loss of appetite [52]. Furthermore, males were found to be more prone to wasting, underweight, and stunting compared to females, consistent with results from prior research conducted in Sierra Leone [14] and Sub-Saharan Africa [53]. This gender difference may be explained by the slower development of lungs in males, rendering them more susceptible to recurrent respiratory infections such as bronchiolitis, pneumonia, otitis media, and hyperactive airway disease. Consequently, this could also contribute to the higher likelihood of stunting among male children [54].

As seen in previous research [44, 55], the present study also indicated that children whose mothers had fewer than four prenatal visits during pregnancy were more likely to experience the coexistence of all three dimensions compared to children whose mothers had four or more prenatal visits. Typically, mothers who engage in prenatal programs receive valuable information on general healthcare and nutrition practices, knowledge that may be lacking among mothers who do not attend such programs [56]. Consequently, the lack of prenatal visits may lead to inadequate understanding of proper dietary habits, potentially contributing to the likelihood of their children experiencing under-nutrition-related issues [56]. Regular prenatal care visits have been shown to reduce the occurrence of stunting, underweight, and wasting in children; therefore, encouraging mothers to seek prenatal care is crucial [56]. This finding aligns with other studies [53, 57] which found that children born outside of health facilities were more likely to experience severe stunting, wasting, and underweight compared to those born in health facilities. One possible explanation is that mothers delivering outside medical facilities might not have had access to professional assistance [57].

The current investigation revealed a significant association between the occurrence of stunting, wasting, and underweight and the presence of fever and diarrhea. Consistent with previous research [12, 47], children who experienced diarrhea and fever in the two weeks preceding the survey were more likely to be wasted, stunted, and underweight compared to those who did not. This

could be attributed to the negative impact of diarrhea and fever on digestion, appetite, and nutrient absorption, all of which can contribute to malnutrition. Additionally, undernourished children are more susceptible to bouts of fever and diarrhea, and the occurrence of these illnesses may exacerbate weight loss and malnutrition in children [12].

According to the current study, children from rural areas were more likely to exposed for experiencing for stunting and underweight than those from urban areas. This urban-rural discrepancy in stunting and underweight prevalence, as observed in our study, has also been documented in previous research [12, 53]. Variations in socioeconomic conditions and access to prenatal care between urban and rural settings may contribute to this disparity [58].

Our research identified financial status as one of the most significant indicators of stunting. Children from middle-class and lower-class households were more susceptible to stunting compared to those from wealthier households. This finding is consistent with studies conducted in Gambia [20], Nigeria [19], and Ethiopia [25], suggesting that stunting serves as a marker for food insecurity and poverty [59]. Children in low-income households often lack access to clean water, sufficient food, and adequate sanitation, increasing their susceptibility to infectious diseases such as diarrhea illnesses, intestinal parasites, and acute respiratory infections, all of which are associated with chronic under-nutrition [60].

The study also found that a child's risk of malnutrition rises with the number of under-five children in the household, consistent with earlier research conducted in Ethiopia [61]. This underscores the role of household composition in exacerbating under-nutrition. Similarly, our findings regarding the association between anemia and under-nutrition align with previous research [20, 61]. One possible explanation is that poor dietary practices contribute to both poor health and susceptibility to infections, exacerbating the effects of micro-nutrient deficiencies on anemia prevalence. Malnourished children are also prone to deficiencies in micro-nutrients like iron, vitamin A, vitamin B12, and folic acid, essential for red blood cell production and DNA synthesis, which can lead to anemia [62]. The coexistence of malnutrition and anemia may result from shared causes, with various forms of malnutrition working together to induce anemia. Additionally, malnutrition-related damage to the intestinal epithelium may impair nutrient absorption, further contributing to anemia progression [63], thereby hindering childhood development.

Consistent with previous research, our results also indicated that children whose mothers were not employed faced a higher risk of underweight and wasting compared to those with working mothers [53]. A mother's employment status serves as a proxy for her financial ability to afford nutritious food and healthcare [64, 65]. When mothers are unable to meet their children's dietary needs due to unemployment, their children become highly vulnerable. Similarly, in line with earlier studies [20, 61], children who received vitamin A supplementation before six months of age had a reduced prevalence of underweight and wasting. Vitamin A deficiency increases the risk of mortality from common childhood infections such as diarrhea and is the leading cause of preventable childhood blindness. Regular supplementation with high doses of vitamin A is a proven and cost-effective intervention [66], shown to reduce all-cause mortality by 12 to 24% [66]. Therefore, supporting programs aimed at reducing child mortality should prioritize initiatives promoting regular vitamin A supplementation.

Children born to mothers between the ages of 15 and 20 had a lower risk of stunting compared to those born to mothers aged 20 to 34 and 35 and above. This finding aligns with research conducted in Nigeria [67]. One possible explanation is that teenage mothers, compared to more experienced ones, may be less likely to utilize healthcare services such as immunizations and exhibit poorer health-seeking behaviors [3, 67]. The source of drinking water significantly influences stunting, with stunting being more prevalent in households without access to improved water sources compared to those with such access. This finding is consistent with earlier studies conducted in Ethiopia [68] and east Africa [12]. A lack of access to safe drinking water can increase the incidence of diarrhea among children under five, contributing to malnutrition [69]. Research findings [70, 71] indicate that children from households headed by women were less likely to experience wasting compared to those from households headed by men. This finding is consistent with numerous studies showing that women allocate more of their income to food and childcare. Therefore, households where women have some influence over income tend to have better nutritional outcomes, particularly among children [72].

Strengths and weaknesses

It's important to acknowledge several limitations in this study stemming from the datasets utilized. Firstly, the study relied on survey data collected over different time periods, posing challenges in harmonizing changes in population characteristics across these periods. Additionally, most survey questions pertained to events within the past five years, potentially leading to inaccuracies due to recall bias among respondents, which could have influenced the final results. However, despite these limitations, the study drew robust conclusions by pooling data from 14 West African countries and employing consistent analytical methodology. Moreover, the findings

hold potential applicability to other emerging regions given the cross-sectional nature of the data.

Conclusion

The study shed light on the prevalence of poor nutritional outcomes among under-five children across 14 West African countries. It underscored that approximately one-quarter of children suffer from stunting, nearly one-fifth are underweight, and 9% are wasted. These adverse nutritional outcomes were attributed to various factors, including maternal and paternal education levels, access to adequate toilet facilities, maternal body mass index, type of birth, child's age, antenatal care attendance, place of delivery, recent episodes of diarrhea and fever, household wealth status, child's gender and size, and rural or urban residence.

Addressing these challenges requires multifaceted interventions. Efforts should focus on poverty alleviation at both individual and household levels, enhancing educational opportunities for women, improving living conditions in rural areas, promoting antenatal care attendance among pregnant women, and increasing awareness among women of reproductive age about optimal child nutrition practices. Additionally, substantial investments are needed in healthcare systems across West African countries to ensure adequate provision of nutritious supplemental foods for children under five, aiming to reduce the risk of stunting, underweight, and wasting in this vulnerable population.

Abbreviations

DHS	Demographic health survey
EAs	Enumeration areas
GOLM	Generalized Ordered Logit Model
Ref.	Reference Category
HAZ	Height for age standardized score
ICF	International Coaching Federation
PPM	Partial Proportional Odds Model
WAZ	Weight for age standardized score
WHZ	Weight for height standardized score
OR	Odds ratio

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Author contributions

Abebew Aklog Asmare, Awoke Seyoum Tegegne, Denekew Bitew Belay, and Yitateku Adugna Agmas all made a significant equal contribution to the work reported, whether that is in the conception, study design, execution, acquisition of data, analysis and interpretation, or in all of these areas; took part in drafting, revising, or critically reviewing the article; gave final approval of the version to be published; and agreed on the journal to which the article has been submitted.

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Data availability

The data used in this study came from the Measure DHS program (https://dhsprogram.com/Data/terms-of-use.cfm) and can be obtained using the protocol indicated in the Methods section. Additional documentation on ethical problems related to the surveys is accessible at http://dhsprogram.com.

Declarations

Ethics approval and consent to participate

The current study was based on an analysis of publicly available secondary data that had all identification information removed. ICF Macro's Institutional Review Board (IRB) in Fairfax, Virginia, USA, reviewed and approved the MEASURE DHS Project Phase 3. That approval covers the DHS from 2010 to 2018. ICF Macro's IRB met the United States Department of Health and Human Services' criteria for "Protection of Human Subjects" (45 CFR 46). The IRB-approved processes for DHS public use datasets do not identify respondents, households, or sample communities. The data files contain no names or household addresses. The geographic identifiers only extend to the regional level. Each enumeration region (Primary Sampling Unit) has a PSU number in the data file, but there are no labels indicating their names or locations. In surveys that collect GIS coordinates in the field, the coordinates are only for the entire enumeration area (EA), not for individual houses, and the measured coordinates are randomly shifted within a vast geographic area, making it impossible to identify specific enumeration areas. In addition, for participants under the age of 16, a parent or guardian provided written informed consent. The DHS Program has consistently maintained confidentiality and informed consent over the years. We have express permission to utilize the data from ICF Macro. This study did not require any further permission. The data owners can be contacted at https://dhsprogram.com/Data/terms-of-use.cfm, and data can be found at https://www.dhsprogram.com/data/dataset_admin/login_main.cfm. Further documentations on ethical issues relating to the surveys are available at http://dhsprogram.com. We confirm that all methods were carried out in accordance with the relevant guidelines and regulation.

Consent for publication

Not applicable.

Competing interests

The authors declare no competing interests.

Conflict of interest

Authors declare that there was no conflict of interest among authors or between authors and institutions.

Author details

[1]Department of Statistics, College of Science, Bahir Dar University, P.O. Box 79, Bahir Dar, Ethiopia
[2]Department of Statistics, College of Natural and Computational Science, Mekdela Amba University, P.O. Box 32, Tuluawlyia, Ethiopia
[3]School of Health Systems and Public Health, Faculty of Health Science, University of Pretoria, Pretoria, South Africa
[4]Department of Development Studies, College of Humanities and Development Studies, China Agricultural University, Beijing 100083, China
[5]Department of Rural Development and Agricultural Extension, College of Agriculture and Natural Resources, Mekdela Amba University, P. O. Box 32, Tuluawlyia, Ethiopia

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