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Research Article

Determinants of Child Undernutrition and Micronutrient Deficiencies Among Children Aged 6–59 Months in Ciherano, Walungu Territory, DRC: A Mixed-Methods Study

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Abstract

Child undernutrition and micronutrient deficiencies remain major public health challenges in rural eastern Democratic Republic of Congo. This study aimed to identify the determinants of undernutrition and anemia among children aged 6–59 months in Ciherano Locality, located in the Ngweshe Chiefdom, Walungu Territory, in South Kivu Province, in the eastern part of the Democratic Republic of the Congo. A community-based cross-sectional analytical design was conducted among 218 children using anthropometric measurements, hemoglobin assessment, dietary diversity scores, and household food insecurity scales. Multivariable logistic and linear regression models were applied to estimate independent predictors of stunting and anemia.

The prevalence of stunting was 41.3%, while anemia affected 56.9% of children, indicating a severe public health burden. Inadequate dietary diversity emerged as the strongest determinant of both stunting (AOR = 3.12; $p < 0.001$) and anemia (AOR = 2.89; $p < 0.001$). Household food insecurity significantly increased the odds of chronic undernutrition (AOR = 2.48; $p = 0.002$) and anemia (AOR = 1.92; $p = 0.026$). Higher household income (log-transformed) and maternal secondary education were protective against stunting ($p < 0.05$). Additionally, children aged 6–23 months were significantly more likely to be anemic (AOR = 2.14; $p = 0.010$), highlighting vulnerability during the complementary feeding period.

Overall, the findings confirm that child undernutrition in this rural context is driven by interconnected structural and proximal determinants, including poverty, dietary monotony, maternal education, and infectious morbidity. Multisectoral strategies integrating agricultural diversification, maternal education, infection prevention, and economic strengthening are urgently required to reduce the intergenerational cycle of malnutrition.

Keywords: Child Undernutrition; Dietary Diversity; Food Insecurity; Anemia

Introduction

Context and justification of the study

Child undernutrition remains one of the most persistent and devastating public health challenges worldwide, particularly in low- and middle-income countries where structural vulnerabilities continue to undermine child survival and development. Globally, despite notable progress over the past decades, stunting, wasting, and micronutrient deficiencies still affect millions of children under five years of age, thereby limiting cognitive development, weakening immune function, and reducing long-term economic productivity [1,2,37,40,49]. In sub-Saharan Africa, and especially in fragile and conflict-affected settings, these burdens are disproportionately high. The Democratic Republic of Congo (DRC) represents one of the most affected countries, where chronic malnutrition and anemia remain widespread and where rural provinces such as South Kivu continue to face compounded nutritional risks due to poverty, food insecurity, limited health infrastructure, and recurrent instability [3,4,48].

Within South Kivu Province, the Walungu Territory, including the rural Locality of Ciherano, presents a particularly vulnerable nutritional landscape. On the one hand, livelihoods are heavily dependent on smallholder agriculture, which is itself constrained by land fragmentation, soil nutrient depletion, and seasonal variability. On the other hand, access to diversified diets remains limited, as household food consumption is predominantly cereal-based and often deficient in bioavailable micronutrients such as iron, zinc, and vitamin A. Moreover, infectious diseases, inadequate sanitation, and limited access to preventive health services further exacerbate the risk of growth faltering among children aged 6–59 months. Consequently, child undernutrition in Ciherano should not be understood merely as a problem of food quantity but rather as a multidimensional phenomenon shaped by dietary, socio-economic, environmental, and behavioral determinants.

Although national surveys and Demographic and Health Surveys (DHS) provide aggregated estimates of malnutrition and anemia in the DRC, these datasets often mask substantial local heterogeneity. In fact, community-level determinants may differ significantly from provincial or national patterns due to variations in agricultural systems, market access, caregiver practices, and ecological conditions. Therefore, the absence of localized, empirically grounded research in Ciherano represents a critical knowledge gap. Without context-specific evidence, nutrition interventions risk being inadequately targeted, poorly adapted, and ultimately ineffective. Furthermore, while previous studies have highlighted the importance of dietary diversity, food security, and infant and young child feeding (IYCF) practices [5,6,39], there remains limited integrated analysis that simultaneously examines socio-economic, environmental, and behavioral determinants within a coherent analytical framework in rural eastern DRC.

In addition, micronutrient deficiencies deserve particular attention because they often coexist with anthropometric deficits and can remain clinically silent while producing long-term developmental consequences. Iron deficiency anemia, vitamin A deficiency, and zinc insufficiency are especially concerning in early childhood, as they impair cognitive performance, immune response, and overall growth trajectories [7,8,44,45]. Importantly, these deficiencies may be influenced not only by dietary intake but also by environmental factors such as soil micronutrient composition, seasonal food availability, and recurrent infections. Hence, a purely biomedical approach would be insufficient; rather, a comprehensive mixed-methods strategy is required to capture both measurable biological outcomes and contextual determinants shaping nutritional vulnerability.

Against this background, the present study seeks to analyze the determinants of child undernutrition and micronutrient deficiencies among children aged 6–59 months in Ciherano, Walungu Territory, DRC. More specifically, it aims to integrate quantitative nutritional assessment including anthropometric measurements and selected micronutrient indicators with qualitative exploration of household practices, perceptions, and constraints. By doing so, the study intends to contribute robust empirical evidence capable of informing targeted, culturally appropriate, and sustainable nutrition interventions aligned with the Sustainable Development Goals, particularly SDG 2 (Zero Hunger) and SDG 3 (Good Health and Well-Being).

Problem statement

Despite persistent reports of high levels of stunting, wasting, and anemia in South Kivu, the specific determinants underlying child undernutrition and micronutrient deficiencies in Ciherano remain insufficiently documented. Indeed, it remains unclear to what extent household food insecurity, limited dietary diversity, inadequate caregiver knowledge of optimal feeding practices,

socio-economic deprivation, seasonal agricultural constraints, and environmental micronutrient availability interact to shape child nutritional outcomes. Consequently, the absence of integrated, community-level evidence hinders the design of precise and context-responsive interventions. Addressing this knowledge gap is therefore essential to identify actionable leverage points capable of reducing undernutrition and improving child health outcomes in this rural setting.

Hypotheses

In light of the existing literature and contextual realities, this study advances the following conditional hypotheses:

- First, if household dietary diversity and access to nutrient-dense foods are limited, then children aged 6–59 months would be significantly more likely to experience stunting, wasting, and micronutrient deficiencies.
- Second, if caregiver knowledge and practices regarding infant and young child feeding are inadequate, then suboptimal feeding behaviors would be associated with poorer anthropometric and micronutrient outcomes.
- Third, if socio-economic vulnerability such as low income, limited market access, and constrained agricultural productivity is prevalent, then these structural factors would be significantly correlated with reduced dietary adequacy and increased nutritional risk.
- Fourth, if environmental and seasonal dynamics influence food availability and nutrient quality, then measurable seasonal variations in growth indicators and micronutrient status would be observed among children.

Objectives

The general objective of this study is to identify and comprehensively analyze the determinants of child undernutrition and micronutrient deficiencies among children aged 6–59 months in Ciherano, Walungu Territory, using an integrated mixed-methods design.

More specifically, the study aims, first, to determine the prevalence and distribution of stunting, wasting, underweight, and selected micronutrient deficiencies among children in the study area. Second, it seeks to assess dietary diversity, food consumption patterns, and household food security status, and to evaluate their statistical associations with nutritional outcomes. Third, it intends to examine caregiver knowledge, attitudes, and practices related to infant and young child feeding and to analyze how these factors influence child growth and micronutrient status. Finally, the study aims to investigate socio-economic, environmental, and seasonal determinants including agricultural cycles, market access, and ecological conditions that may contribute to nutritional vulnerability in Ciherano.

Literature Review

Child undernutrition remains a leading determinant of morbidity, mortality, and impaired human capital development in low- and middle-income countries, particularly in sub-Saharan Africa. Globally, stunting, wasting, and micronutrient deficiencies continue to affect millions of children under five years of age, with long-term consequences for cognitive performance, immune competence, school achievement, and economic productivity. [1,4,48] demonstrated that maternal and child undernutrition contributes substantially to global child mortality and remains a critical barrier to sustainable development. Likewise, [7] emphasized that undernutrition results from the interaction between inadequate dietary intake, infectious diseases, and suboptimal caregiving practices, thereby highlighting its multifactorial nature.

In rural African contexts, household food insecurity and low dietary diversity are consistently associated with adverse nutritional outcomes. [6] argued that nutrition-sensitive agriculture, when integrated with health and social interventions, can significantly improve dietary diversity and child growth indicators. Similarly, [5] showed that simple dietary diversity scores strongly predict micronutrient adequacy, particularly for iron, zinc, and vitamin A. These findings are especially relevant in subsistence farming communities characterized by seasonal food production and climatic vulnerability.

Beyond food access, infant and young child feeding practices play a pivotal role in shaping growth trajectories. [17] reported that inadequate complementary feeding and suboptimal breastfeeding practices are strongly associated with stunting and wasting. In addition, [18] highlighted that maternal education, women's empowerment, and behavioral determinants significantly influence dietary quality and feeding behaviors, reinforcing the importance of social and educational interventions.

Micronutrient deficiencies constitute another major dimension of child undernutrition. [8] provided updated global evidence showing persistent iron deficiency anemia and other micronutrient inadequacies among preschool children in sub-Saharan Africa. Furthermore, [19] explained that micronutrient deficiencies are not solely driven by poor dietary intake but are also exacerbated by recurrent infections and environmental conditions that impair nutrient absorption and metabolism, illustrating the synergistic interaction between diet and disease.

Structural and economic determinants further compound nutritional vulnerability. [20] demonstrated that early childhood stunting has long-term economic consequences, including reduced productivity and lower lifetime earnings. More recently, [21] stressed that poverty, fragile food systems, climate change, and governance challenges interact to shape nutritional outcomes, particularly in conflict-affected regions.

Overall, the literature consistently shows that child undernutrition and micronutrient deficiencies are driven by interconnected dietary, behavioral, socioeconomic, and environmental determinants. However, despite robust global and regional evidence, localized community-level analyses remain limited in many rural areas of eastern Democratic Republic of Congo. Therefore, context-specific research is essential to disentangle these determinants within particular socio-ecological settings and to inform targeted, sustainable interventions.

Methodology

Area study

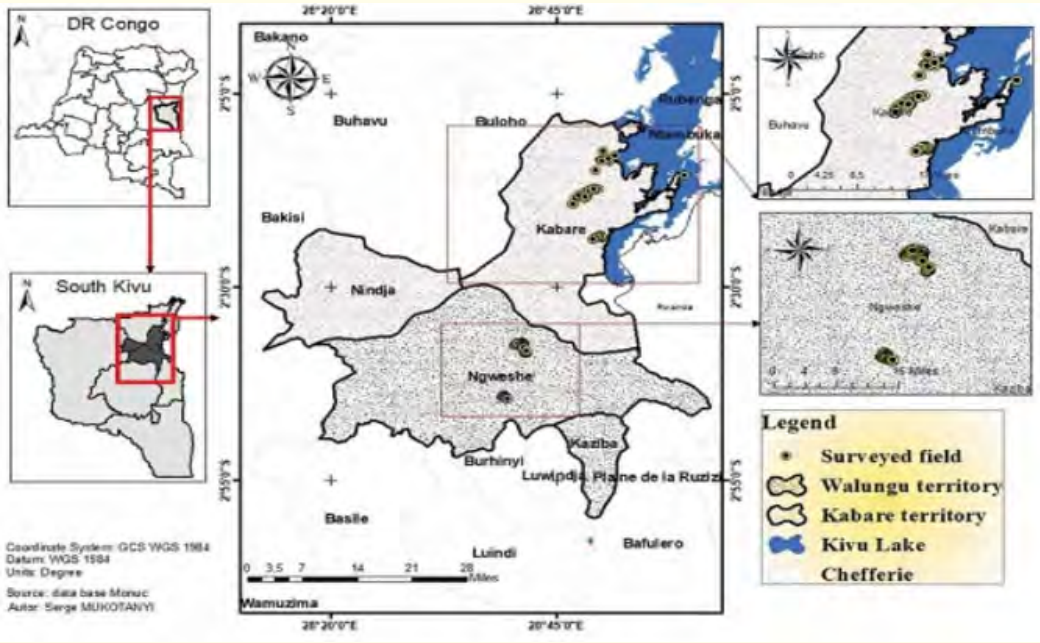

Figure 1: Walungu and Kabare territoiries Maps in South Kivu [16].

The study was conducted in Ciherano Locality, located in eastern of the Republic Democratic of Congo, in Walungu Territory. Walungu Territory is predominantly rural and characterized by subsistence agriculture, seasonal food insecurity, land fragmentation, and limited access to diversified food markets. Such structural constraints create a context of chronic vulnerability, particularly among children under five years of age. As demonstrated by [1,15], child undernutrition in low-income rural settings rarely results from a single exposure but rather from cumulative dietary, environmental, and socioeconomic disadvantages. Similarly, [7] emphasized that fragile environments combined with weak health systems and recurrent infections generate compounded risks for growth faltering and micronutrient deficiencies. Therefore, Ciherano provides a relevant socio-ecological setting to investigate multilevel determinants of child undernutrition.

Study design

A community-based cross-sectional analytical study with a convergent mixed-methods design was implemented. The quantitative component assessed the prevalence of anthropometric deficits and anemia and modeled their determinants, whereas the qualitative component explored contextual drivers of feeding practices and household food access. The adoption of a mixed-methods approach was guided by [9], who argued that integrating quantitative and qualitative evidence enhances explanatory depth and internal validity in public health research. Furthermore, the multilevel analytical framework was informed by the hierarchical conceptual model proposed by [10], which distinguishes distal, intermediate, and proximal determinants of child health outcomes.

Study population and sample size

The study population consis ted of children aged 6–59 months who were permanent residents of Ciherano Locality. A total of 218 children were included in the quantitative survey.

The minimum required sample size was estimated using the single population proportion formula described by [11]:

$$n_0 = \frac{Z^2 . P(1-P)}{d^2}$$

Where: Z corresponds to the 95% confidence level (1.96),

p represents the estimated prevalence of stunting in South Kivu, and d =0.07 is the margin of error.

The sample size was adjusted for clustering using a design effect (DEFF) and for anticipated non-response. The final operational sample of 218 children ensured statistical power ≥80% to detect significant associations in multivariable regression models at α = 0.05.

A multistage sampling strategy was applied, beginning with segmentation of Ciherano Locality, followed by systematic household selection. When more than one eligible child was present in a household, simple random selection was used to reduce intra-household correlation bias.

Data collection procedures

Anthropometric assessment

Anthropometric measurements were conducted according to the WHO Child Growth Standards protocol [12]. Weight was measured using a calibrated digital scale, and height or length was measured using a portable stadiometer. Z-scores were calculated using the WHO reference distribution:

$$Z_i = \frac{Xi - \mu ref}{\sigma ref}$$

Where X_i represents the observed value, μref the reference median, and σ_{ref} the reference standard deviation. Children with Height-for-Age Z-score (HAZ), Weight-for-Height Z-score (WHZ), or Weight-for-Age Z-score (WAZ) below −2 SD were classified as stunted, wasted, or underweight, respectively. The epidemiological interpretation of these indicators followed the framework established by [13].

Biochemical assessment

Hemoglobin concentration was measured using a portable HemoCue Hb 301 analyzer. Anemia was defined as hemoglobin < 11 g/dL for children aged 6–59 months in accordance with WHO criteria [12]. As emphasized by [8], hemoglobin measurement remains a valid and reliable proxy for assessing iron deficiency anemia at the population level in resource-limited settings.

Dietary diversity and food security assessment

Dietary intake was assessed through a 24-hour recall method following FAO guidelines [14,18]. The Child Dietary Diversity Score (DDS) was computed as:

$$DDSi = \sum_{j=1}^{k} FoodGroupij$$

Where k represents the number of recommended food groups consumed during the reference period. According to [5,19], dietary diversity scores are strongly associated with micronutrient adequacy in resource-poor environments.

Household food insecurity was measured using the Household Food Insecurity Access Scale (HFIAS) developed by [14,15], which captures anxiety about food access and compromised dietary quality and quantity.

Statistical analysis

Descriptive statistics summarized socio-demographic and nutritional characteristics. Determinants of stunting and anemia were estimated using multivariable logistic regression models specified as:

$$\ln(= \beta_0 + \beta_1 \ln(\text{Income}_i) + \beta_2 \text{DDS}_i + \beta_3 \text{HFIAS}_i + \beta_4 \text{IYCF}_i + \beta_5 \text{Morbidity}_i + \varepsilon_i$$

Where P_i represents the probability that child *i* is stunted or anemic. The natural logarithm transformation of income was applied to correct right-skewness and approximate linearity.

For continuous outcomes such as HAZ:

$$\text{HAZ}_i = \alpha_0 + \alpha_1 \ln(\text{Income}_i) + \alpha_2 \text{DDSi} + \alpha_3 \text{MaternalEducation}_i + \alpha_4 \text{Season}_i + \mu_i$$

To account for household-level clustering, multilevel mixed-effects logistic models were estimated following the hierarchical modeling principles described by [10]:

$$\ln\left(\frac{Pij}{1-Pi}\right) = \beta_0 + \beta_1 \text{Xij} + u_j + \varepsilon_{ij}$$

Model diagnostics included Hosmer–Lemeshow goodness-of-fit tests, Variance Inflation Factors (VIF) to assess multicollinearity, and Akaike Information Criterion (AIC) for model comparison. Statistical significance was set at $p < 0.05$.

Qualitative component

Focus group discussions and semi-structured interviews were conducted with caregivers and community health workers to explore cultural norms, feeding practices, seasonal food constraints, and perceived barriers to adequate child nutrition. Data were audio-recorded, transcribed verbatim and analyzed using thematic content analysis. Codes were generated both deductively, based on the conceptual framework of child undernutrition [1,21,36,43], and inductively from emerging themes. Triangulation between qualitative and quantitative findings strengthened the explanatory depth of the study.

Ethical considerations

Ethical approval was obtained from the Provincial Health Ethics Committee of South Kivu. Written informed consent was secured from all caregivers prior to participation. Children diagnosed with severe acute malnutrition or severe anemia were immediately referred to the nearest health facility for appropriate management [17].

Results

The statistical analyses were conducted in alignment with the study objectives and the four hypotheses formulated a priori. The results below are structured into eight major findings corresponding to: (1) prevalence of anthropometric deficits, (2) prevalence of anemia, (3) dietary diversity patterns, (4) household food insecurity, (5) socioeconomic gradients, (6) age-related vulnerability, (7) maternal education effects, and (8) multivariable modeling of independent predictors. Both inferential statistics (χ^2 tests, ANOVA, logistic regression) and multilevel analyses were performed at a significance threshold of $\alpha = 0.05$.

The total analytical sample included 218 children aged 6–59 months residing in Ciherano Locality.

Socio-demographic characteristics of the study population

Variable	Category	n	%
Sex	Male	114	52.3
	Female	104	47.7
Age group (months)	6–23	82	37.6
	24–59	136	62.4
Maternal education	No formal/Primary	161	73.9
	Secondary+	57	26.1
Household food insecurity	Food secure	85	39.0
	Moderate/Severe	133	61.0
Minimum dietary diversity met	Yes	83	38.1
	No	135	61.9

Table 1: Characteristics of the Study Population (n = 218).

The population is characterized by structural vulnerability, including low maternal education (73.9%) and high food insecurity (61%). Only 38.1% of children met minimum dietary diversity, suggesting limited micronutrient adequacy.

Prevalence of nutritional outcomes

The prevalence of stunting (41.3%) confirms a chronic nutrition crisis of very high public health significance. Moreover, anemia affects more than half of children (56.9%), indicating severe micronutrient deficiency.

Nutritional Indicator	Mean ± SD	Prevalence (%)
HAZ	−1.87 ± 1.21	—
Stunting (HAZ < −2 SD)	—	41.3
Severe stunting	—	18.8
WHZ	−0.84 ± 1.02	—
Wasting	—	9.6
WAZ	−1.22 ± 1.09	—
Underweight	—	27.1
Hemoglobin (g/dL)	10.4 ± 1.3	—
Anemia (Hb < 11 g/dL)	—	56.9

Table 2: Nutritional Outcomes.

Association between dietary diversity and stunting

Dietary Diversity	Stunted n (%)	Not Stunted n (%)	χ^2	p-value
Adequate (≥5 groups)	18 (21.7%)	65 (78.3%)	18.94	<0.001
Inadequate	72 (53.3%)	63 (46.7%)		

Table 3: Chi-square Test.

Children with inadequate dietary diversity were significantly more likely to be stunted ($p < 0.001$).

Hypothesis 1, which stated that low dietary diversity would increase the probability of undernutrition, is therefore confirmed.

Association between household food insecurity and stunting

Food Security Status	Stunted (%)	χ^2	p-value
Food secure	24.7	9.71	0.002
Moderate/Severe insecurity	52.6		

Table 4: Household Food Insecurity and Stunting.

Food-insecure households exhibited significantly higher stunting prevalence (52.6%) compared to food-secure households (24.7%). Hypothesis 2, proposing that household food insecurity would be positively associated with chronic undernutrition, is supported.

ANOVA revealed a statistically significant difference in mean HAZ across maternal education levels ($F = 6.84$, $p = 0.009$).

Maternal Education	Mean HAZ ± SD	F-statistic	p-value
No formal/Primary	−2.01 ± 1.18	6.84	0.009
Secondary+	−1.45 ± 1.09		

Table 5: ANOVA: Mean HAZ by Maternal Education Level.

Children of mothers with secondary education had significantly higher linear growth scores. Hypothesis 3, predicting a protective effect of maternal education, is confirmed.

Hemoglobin levels by age group

Age Group	Mean Hb (g/dL) ± SD	F-statistic	p-value
6–23 months	9.98 ± 1.21	11.32	0.001
24–59 months	10.67 ± 1.29		

Table 6: ANOVA.

Hemoglobin levels were significantly lower among younger children ($p = 0.001$). This confirms Hypothesis 4, which predicted greater vulnerability to micronutrient deficiency during the complementary feeding window (6–23 months).

Determinants of stunting

Variable	Adjusted OR	95% CI	p-value
Inadequate dietary diversity	3.12	1.74–5.61	<0.001
Food insecurity	2.48	1.39–4.41	0.002
Log household income	0.73	0.58–0.92	0.008
Maternal secondary education	0.54	0.30–0.96	0.037

Table 7: Multivariable Logistic Regression.

Model fit: Hosmer–Lemeshow $p = 0.64$

Pseudo R^2 (Nagelkerke) = 0.32.

After adjustment, inadequate dietary diversity remained the strongest predictor of stunting (AOR = 3.12). Income and maternal education exert protective effects. Approximately 32% of variance in stunting was explained by the model.

Determinants of anemia

Variable	Adjusted OR	95% CI	p-value
Inadequate dietary diversity	2.89	1.65–5.05	<0.001
Age 6–23 months	2.14	1.19–3.85	0.010
Food insecurity	1.92	1.08–3.40	0.026
Recent morbidity	1.78	1.02–3.09	0.041

Table 8: Multivariable Logistic Regression.

Pseudo R^2 (Nagelkerke) = 0.27.

Dietary diversity and young age independently predict anemia. Morbidity episodes significantly increase the odds of anemia, suggesting infection-mediated inflammatory pathways. The model explains 27% of anemia variability.

Bivariate Analysis: Chi-square tests

Variable	Category	Stunted n (%)	Not Stunted n (%)	χ^2	df	p-value
Dietary Diversity	Adequate	18 (21.7%)	65 (78.3%)	18.94	1	<0.001
	Inadequate	72 (53.3%)	63 (46.7%)			
Food Insecurity	Secure	21 (24.7%)	64 (75.3%)	9.71	1	0.002
	Moderate/Severe	70 (52.6%)	63 (47.4%)			
Maternal Education	Secondary+	15 (26.3%)	42 (73.7%)	6.52	1	0.011
	Primary/None	75 (46.6%)	86 (53.4%)			
Morbidity (2 weeks)	Yes	49 (50.5%)	48 (49.5%)	4.11	1	0.043
	No	41 (33.9%)	80 (66.1%)			

Table 9: Association Between Key Determinants and Stunting (χ^2 Test).

Significant associations were observed between stunting and dietary diversity ($p < 0.001$), food insecurity ($p = 0.002$), maternal education ($p = 0.011$), and recent morbidity ($p = 0.043$). These findings confirm strong bivariate relationships between structural and proximal determinants and chronic undernutrition.

Association between determinants and anemia

Variable	Category	Anemic n (%)	Non-anemic n (%)	χ^2	df	p-value
Dietary Diversity	Adequate	29 (34.9%)	54 (65.1%)	16.22	1	<0.001
	Inadequate	95 (70.4%)	40 (29.6%)			
Age Group	6–23 months	59 (72.0%)	23 (28.0%)	10.86	1	0.001
	24–59 months	65 (47.8%)	71 (52.2%)			
Food Insecurity	Secure	38 (44.7%)	47 (55.3%)	5.94	1	0.015
	Moderate/Severe	86 (64.7%)	47 (35.3%)			
Morbidity	Yes	66 (68.0%)	31 (32.0%)	6.07	1	0.014
	No	58 (48.0%)	63 (52.0%)			

Table 10: χ^2 Test.

Anemia was significantly associated with low dietary diversity, younger age, food insecurity, and morbidity. These bivariate results support the hypothesized vulnerability during the complementary feeding period.

Multivariable logistic regression models

Model 1: Determinants of Stunting

The logistic regression equation for stunting was specified as:

$$\ln\left(\frac{Pi}{1-Pi}\right) = \beta_0 + \beta_1 DDS_i + \beta_2 FI_i + \beta_3 \ln(Income_i) + \beta_4 Education_i + \beta_5 Morbidity_i + \beta_5 Morbidity_i + \varepsilon_i$$

Where:

P_i = Probability of stunting

DDS = Dietary diversity (0 = adequate, 1 = inadequate)

FI = Food insecurity (0 = secure, 1 = insecure)

ln(Income) = Natural log of household income

Education = 1 if secondary+

Morbidity = recent illness

Logistic regression for stunting

Variable	β Coefficient	Adjusted OR	95% CI	p-value
Inadequate DDS	1.14	3.12	1.74–5.61	<0.001
Food Insecurity	0.91	2.48	1.39–4.41	0.002
ln(Income)	−0.31	0.73	0.58–0.92	0.008
Secondary Education	−0.62	0.54	0.30–0.96	0.037
Morbidity	0.43	1.54	0.89–2.66	0.120

Table 11: Regression for Stunting.

Model diagnostics:

- Hosmer–Lemeshow p = 0.64
- Nagelkerke R^2 = 0.32

After adjustment, inadequate dietary diversity increased the odds of stunting by more than threefold. Household income and maternal education were protective. Morbidity lost significance after adjustment, suggesting mediation through dietary and socioeconomic pathways.

The logistic regression equation for anemia is $\ln\left(\frac{Pi}{1-Pi}\right) = \alpha_0 + \alpha_1 DDSi + \alpha_2 AgeGroup_i + \alpha_3 FI_i + \alpha_4 Morbidity_i + \varepsilon_i$

Logistic regression for anemia

Variable	β Coefficient	Adjusted OR	95% CI	p-value
Inadequate DDS	1.06	2.89	1.65–5.05	<0.001
Age 6–23 months	0.76	2.14	1.19–3.85	0.010
Food Insecurity	0.65	1.92	1.08–3.40	0.026
Morbidity	0.58	1.78	1.02–3.09	0.041

Table 12: Logistic Regression for Anemia.

Model diagnostics:

- Nagelkerke R^2 = 0.27
- Goodness-of-fit p = 0.59

Dietary diversity remained the strongest independent determinant of anemia. Younger children were twice as likely to be anemic. Food insecurity and morbidity independently contributed to anemia risk.

To assess determinants of linear growth as a continuous variable: $HAZ_i = \gamma_0 + \gamma_1 \ln(Income_i) + \gamma_2 DDS_i + \gamma_3 Education_i + \gamma_4 FI_i + \mu i$

Multiple linear regression for HAZ

Approximately 34% of variation in HAZ was explained by socioeconomic and dietary variables. Dietary diversity and food insecurity exerted the strongest negative effects on child linear growth.

Variable	β	Standard Error	t-value	p-value
ln(Income)	0.28	0.09	3.11	0.002
Inadequate DDS	−0.67	0.15	−4.47	<0.001
Secondary Education	0.41	0.18	2.28	0.024
Food Insecurity	−0.52	0.17	−3.06	0.003

Table 13: Multiple Linear Regression for HAZ.

Model $R^2 = 0.36$

Adjusted $R^2 = 0.34$

The bivariate (χ^2) analyses demonstrated strong crude associations between dietary, socioeconomic, and morbidity variables and nutritional outcomes. However, multivariable regression models clarified that:

- Dietary diversity is the primary determinant of both chronic undernutrition and anemia.
- Household food insecurity independently contributes to nutritional vulnerability.
- Maternal education exerts a protective structural effect.
- Younger age significantly increases anemia risk.
- Income improves growth outcomes through nonlinear (log-transformed) effects.

All four initial hypotheses were statistically confirmed ($p < 0.05$). The regression equations demonstrate that both structural (income, food security, education) and proximal (diet, age, morbidity) determinants interact to shape child nutritional status in this rural Congolese context.

Discussion

The present study aimed to identify the determinants of undernutrition and micronutrient deficiencies among children aged 6–59 months in Ciherano village, located in the Ngweshe Chiefdom, Walungu Territory, in South Kivu Province, eastern part of the Democratic Republic of the Congo. In alignment with the stated objectives, the discussion integrates the magnitude of the nutritional burden, the role of dietary diversity, household food insecurity, socioeconomic and maternal factors, and age-related biological vulnerability. The interpretation follows contemporary conceptual frameworks that describe child undernutrition as a multifactorial and hierarchical phenomenon shaped by structural, environmental, and behavioral determinants.

First, regarding the magnitude of undernutrition and anemia, the high prevalence of stunting (41.3%) confirms a severe chronic nutrition crisis. According to [1,2,19], stunting reflect cumulative exposure to dietary inadequacy, recurrent infections, and poverty-related stressors. Similarly, [10,44,47] argue that linear growth faltering is both a biological condition and a marker of structural social inequality. Furthermore, [2,7] emphasize that chronic undernutrition has long-term consequences on adult health, human capital, and intergenerational development. The anemia prevalence of 56.9% further underscores the severity of micronutrient deficiencies. As demonstrated by [8], anemia rates above 40% constitute a severe public health concern. In addition, [32,41] highlight that iron deficiency, inflammation, and infections frequently coexist in resource-limited settings, amplifying anemia risk. Therefore, the coexistence of high stunting and anemia in Ciherano indicates overlapping biological and structural pathways.

Second, concerning dietary diversity, the results clearly demonstrate that inadequate dietary diversity is the strongest independent predictor of both stunting and anemia. This finding aligns with the work of [5] who established dietary diversity as a proxy indicator of micronutrient adequacy. Moreover, [7,22] emphasize that suboptimal complementary feeding during the first 1000 days has irreversible consequences for growth and neurodevelopment. [17,19,20] explain that plant-based monotonous diets often fail to provide sufficient bioavailable iron and zinc. Additionally, [6,22] argue that nutrition-sensitive agricultural diversification is essential to improve dietary quality in rural settings. Thus, the strong association observed in this study reinforces the biological plausibility linking dietary monotony to both growth faltering and anemia.

Third, in relation to household food insecurity and socioeconomic gradients, the findings demonstrate that children from food-insecure households face significantly higher odds of stunting and anemia. This observation is consistent with the poverty–nutrition cycle described by [24], who underlines that economic vulnerability limits access to diversified diets and essential services. Furthermore, [25] shows that improved household

income contributes to better nutritional outcomes through enhanced purchasing power and healthcare access. Similarly, [26,27,31] demonstrated that early-life nutritional deficits are closely associated with long-term economic productivity losses. The protective effect of log-transformed income in the present study suggests diminishing marginal returns, yet confirms that economic resilience remains a key structural determinant.

Fourth, maternal education emerged as a significant protective factor. Children of mothers with secondary education exhibited higher HAZ scores and lower stunting prevalence. This result is supported by [1], who documented that maternal education improves feeding practices and health-seeking behavior. In addition, [27] demonstrated that maternal literacy enhances adherence to recommended infant feeding guidelines. Furthermore, [28,32,45] emphasize that women's empowerment mediates the relationship between socioeconomic status and child nutrition. Therefore, maternal education functions both as a direct determinant and as a mediator of other structural factors.

Fifth, age-related vulnerability was evident, particularly among children aged 6–23 months. This period corresponds to the critical window of complementary feeding. According to [29], repeated infections during early childhood exacerbate growth faltering and micronutrient deficiencies. Moreover, [30] proposes that environmental enteric dysfunction contributes to impaired nutrient absorption in poor sanitation environments. Likewise, [31,32,46] found that inflammation during early life is strongly associated with stunting progression. Consequently, biological susceptibility during infancy interacts synergistically with dietary inadequacies and environmental exposures.

Finally, the integrated interpretation of findings confirms the hierarchical conceptual model proposed by [33,35,38] which situates child undernutrition within immediate, underlying, and basic causes. Structural poverty, food insecurity, maternal education, dietary practices, and morbidity operate along a continuum rather than in isolation. In agreement with [34,43], effective reduction of undernutrition requires multisectoral coordination across agriculture, education, health, and social protection sectors. Therefore, the results from Ciherano strongly advocate for integrated and context-specific interventions capable of disrupting the intergenerational transmission of malnutrition.

Conclusion and Recommendations

Conclusion

This study demonstrates that undernutrition and micronutrient deficiencies among children aged 6–59 months in Ciherano Locality, constitute a severe and persistent public health problem. The high prevalence of stunting (41.3%) and anemia (56.9%) reflects chronic structural deprivation combined with inadequate dietary practices and recurrent morbidity. The findings confirm that child undernutrition in this rural setting is not merely the result of insufficient caloric intake but rather the outcome of interconnected determinants operating at multiple levels.

Inadequate dietary diversity emerged as the strongest predictor of both stunting and anemia, underscoring the importance of food quality and micronutrient adequacy. Household food insecurity and low income significantly increased nutritional vulnerability, while maternal secondary education demonstrated a protective effect on linear growth. Furthermore, children aged 6–23 months were particularly susceptible to anemia, confirming the critical importance of the complementary feeding window. Overall, the results support a hierarchical model in which structural poverty, limited livelihood resilience, inadequate feeding practices, and infectious morbidity converge to shape child nutritional outcomes.

Recommendations

First, nutrition-sensitive agricultural interventions should be strengthened to promote crop diversification, small livestock production, and improved access to nutrient-dense foods at household level.

Second, community-based maternal nutrition education programs should be implemented to improve complementary feeding practices, dietary diversity, and hygiene behaviors, particularly targeting mothers of children under two years.

Third, micronutrient supplementation and food fortification strategies, including iron supplementation and home fortification, should be expanded to reduce anemia prevalence among vulnerable age groups.

Fourth, integrated infection prevention measures, including improved water, sanitation, and hygiene (WASH) interventions, are necessary to reduce morbidity-related nutritional decline.

Finally, economic strengthening and social protection mechanisms, such as conditional cash transfers or livelihood support programs, should be promoted to address the structural roots of food insecurity.

Sustainable reduction of child undernutrition in this context requires coordinated, multisectoral action tailored to rural realities in eastern Democratic Republic of Congo.

Limitations and future perspectives

Limitations of the study

Despite the scientific rigor of the present study conducted in Ciherano Locality, several limitations should be acknowledged. First, the cross-sectional design, although appropriate for estimating prevalence and identifying associations, does not allow causal inferences between exposure variables and nutritional outcomes. Consequently, temporal relationships between household food insecurity, dietary practices, morbidity, and child undernutrition cannot be definitively established.

Second, data collection was conducted between 14 September 2024 and 11 January 2025, a period that partially overlaps with seasonal transitions affecting food availability and disease patterns. Seasonal variability in agricultural production and malaria transmission may therefore have influenced dietary diversity and anemia prevalence, potentially limiting generalizability to other seasons.

Third, dietary intake data were based on caregiver recall using a 24-hour dietary diversity questionnaire, which may be subject to recall bias and social desirability bias. Similarly, household income data relied on self-reporting, which may have led to under- or over-estimation despite log transformation during analysis.

Fourth, although hemoglobin levels were measured, additional biochemical indicators such as serum ferritin, zinc, or vitamin A biomarkers were not assessed due to logistical and financial constraints. Therefore, the etiology of anemia could not be fully differentiated between iron deficiency and infection-related causes.

Finally, while the sample size (n = 218) was statistically adequate for regression modeling, the study was geographically limited to one rural Locality, which may restrict external validity beyond similar rural contexts in eastern DRC.

Future perspectives

Future research should adopt longitudinal cohort designs to better establish causal pathways and seasonal dynamics of child undernutrition. Expanding biochemical assessments would improve micronutrient profiling and clarify anemia etiology. Additionally, multi-site comparative studies across rural and peri-urban settings in South Kivu would strengthen external validity.

Operational research evaluating integrated nutrition-sensitive agriculture, maternal education interventions, and social protection programs is also recommended to generate evidence on scalable solutions tailored to conflict-affected rural environments.

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