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The Triple Burden: How Dietary Diversity, Maternal Education, and Poverty Drive the Malnutrition Syndemic in Sokoto State, Nigeria

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ABSTRACT

Childhood malnutrition in Northern Nigeria remains persistently high. However, the integrated relationship between visible anthropometric failure, underlying biochemical derangements, and socio-demographic determinants has been inadequately characterized. This study aimed to identify independent predictors of malnutrition and quantify the burden of "hidden hunger" among children under five years in Sokoto State, Nigeria. A community-based cross-sectional study was conducted among 150 mother-child pairs attending primary health centers across twelve Local Government Areas in Sokoto State between September 2024 and September 2025. Anthropometric measurements (weight, height, mid-upper arm circumference) and venous blood samples for biomarker analysis (prealbumin, C-reactive protein, serum retinol, hemoglobin, albumin, zinc) were collected. Multivariable binary logistic regression identified independent predictors of underweight (weight-for-age Z-score < -2 standard deviations), with results reported as adjusted odds ratios (AOR) and 95% confidence intervals (CI). The prevalence of underweight was 83.3% (95% CI: 76.5–88.6), with 20.0% severely underweight. Vitamin A deficiency affected 91.3% (95% CI: 86.7–95.9), zinc deficiency 73.3% (95% CI: 66.2–80.4), and anemia 78.7% (95% CI: 72.1–85.3). Critically, 72.3% of children classified as "normal" by mid-upper arm circumference (>12.5 cm) had vitamin A deficiency, and 38.3% had three or more concurrent deficiencies. Multivariable analysis identified three independent predictors: low household dietary diversity (≤4 food groups) was the strongest predictor (AOR = 4.2, 95% CI: 1.8–9.8, p = 0.001); low maternal education (none/Qur'anic only) (AOR = 3.1, 95% CI: 1.3–7.4, p = 0.011); and extreme household poverty (<₦20,000/month) (AOR = 2.8, 95% CI: 1.2–6.5, p = 0.018). Systemic inflammation (elevated C-reactive protein >3 mg/L) affected 78.0% of children, with a dose-response relationship from normal (51.1%) to moderate acute malnutrition (78.7%) to severe acute malnutrition (92.9%) (p < 0.001). The malnutrition crisis in Sokoto State represents "a syndemic" driven by the synergistic interaction of dietary inadequacy, maternal educational deprivation, and extreme poverty. The high prevalence of hidden hunger among anthropometrically normal children reveals that sole reliance on anthropometry misses the majority of micronutrient deficiencies. These findings mandate integrated, multi-sectoral interventions addressing dietary diversity, women's education, poverty alleviation, and infection control simultaneously.

INTRODUCTION

The Global and Regional Context of Childhood Malnutrition

Human capital development in low- and middle-income countries continues to be severely impeded by childhood malnutrition. Previous research has established that under-nutrition contributes directly or indirectly to approximately 45% of all deaths occurring among children under five years worldwide (Black *et al.,* 2013; World Health Organization [WHO], 2023). According to recent joint estimates from United Nations agencies, 150.2 million young children are stunted, 42.8 million are wasted, and 35.5 million are overweight globally. These conditions arise from persistent deficiencies in essential nutrients combined with recurrent infections, suboptimal feeding practices, poor sanitation, and limited healthcare access (UNICEF, WHO, & World Bank, 2024).

Sub-Saharan Africa carries a disproportionately heavy share of this global burden. The region accounts for more than one-third of the world's stunted children and approximately 40% of all global wasting cases (Development Initiatives, 2023; Akombi *et al.,* 2017). Within this region, Nigeria Africa's most populous nation faces one of the highest childhood malnutrition burdens worldwide. Data from the 2018 Nigeria Demographic and Health Survey (NDHS) indicate national stunting prevalence of 35.7%, wasting of 6.5%, and underweight of 22.1%, with pronounced regional variations (National Population Commission [NPC] & ICF, 2019).

The Northern Nigeria Crisis: Sokoto State as a Critical Case

The distribution of malnutrition across Nigeria is highly uneven. Northern Nigeria, particularly the North West geopolitical zone, records some of the nation's worst nutritional indicators. Sokoto State consistently ranks

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among the most severely affected states, with stunting prevalence exceeding 50% in certain local government areas, wasting rates of 18.6%, and underweight prevalence of 28.9% (NPC & ICF, 2019; SMART Nutrition Survey, 2024). These figures substantially exceed WHO emergency thresholds and represent an exceptionally severe public health catastrophe.

Multiple intersecting crises drive the situation in Sokoto. Chronic poverty affects over 80% of households. Female literacy rates remain below 20%, reflecting low maternal education. Climate-sensitive agriculture exacerbates chronic food insecurity. Health infrastructure remains weak, with only 45.3% of children fully immunized. Water, sanitation, and hygiene (WASH) conditions are poor, with 35.3% of the population practicing open defecation. Additionally, regional insecurity has led to recurrent population displacement (National Bureau of Statistics [NBS], 2024; IOM, 2024; Sokoto State Primary Health Care Development Agency [SPHCDA], 2024).

Limitations of Anthropometry and the Hidden Hunger Problem

Anthropometric indicators such as stunting, wasting, and underweight are essential screening tools in resource-limited settings. However, these measures provide only indirect assessments of nutritional status. While they capture visible physical consequences, they may not fully reflect underlying physiological derangements particularly micronutrient deficiencies, which are often termed "hidden hunger" (Gibson, 2005; Muthayya *et al.,* 2013).

Research has shown that children who appear well-nourished based on simple arm circumference measurements may nonetheless be severely deficient in micronutrients essential for immune function, cognitive development, and long-term health (Bailey, West, & Black, 2015). This limitation carries profound implications for public health programming: if interventions target only children with visible wasting, the majority of those with subclinical micronutrient deficiencies will be missed.

The Syndemic Framework

The concept of a "syndemic" has gained increasing recognition in public health. According to Singer and Clair (2003), a syndemic refers to "the synergistic interaction of co-occurring diseases and social conditions that together produce a greater burden than the sum of their individual effects." When applied to child malnutrition, this framework posits that undernutrition, micronutrient deficiencies, and infection interact to amplify combined pathological effects (Mertens *et al.,* 2023). Systemic inflammation, measured using C-reactive protein (CRP), serves as a key biomarker of this pathological interaction (Thurnham *et al.,* 2003).

Study Rationale and Objectives

Several critical evidence gaps persist in the literature. Most previous studies rely primarily on anthropometric measurements without biochemical confirmation of deficiencies. The independent contributions of dietary diversity, maternal education, and poverty remain inadequately quantified. Furthermore, the relationship between systemic inflammation and nutritional status has not been characterized in this specific population.

This study therefore aimed to: (1) identify independent predictors of malnutrition among children under five in Sokoto State using multivariable analysis; (2) quantify the burden of hidden hunger, specifically among anthropometrically "normal" children; and (3) characterize the malnutrition-inflammation syndemic in this setting.

MATERIALS AND METHODS

Study Design and Setting

We employed a community-based, cross-sectional analytical design. The study was conducted in selected Primary Health Centres (PHCs) across twelve Local Government Areas (LGAs) in Sokoto State, Northwest Nigeria, between September 2024 and September 2025. The twelve LGAs were purposively selected to ensure representation from all three senatorial districts and to capture socio-ecological and economic heterogeneity across the state.

Study Population and Sampling

The study population comprised children aged 6 to 59 months and their mothers or caregivers who presented at selected PHCs for routine child welfare services. A total of 150 mother-child pairs were enrolled using a multi-stage sampling technique.

Inclusion criteria: Children aged 6–59 months who had resided in selected communities for at least six months, and whose caregivers provided informed consent.

Exclusion criteria: Severely ill or hospitalized children; children with known chronic medical conditions or congenital abnormalities affecting growth; children currently receiving therapeutic feeding; and those whose caregivers declined consent.

Sample Size Determination

Sample size calculations followed the population proportion formula described by Kish (1965). Assuming a stunting prevalence of 50.2% (based on NDHS 2018), with a 95% confidence level, 5% margin of error, design effect of 1.5, and 10% non-response rate, the minimum target sample was 643 children. Due to logistical and security constraints in the study area, the final achieved sample was 150. Post-hoc precision analysis confirmed that despite wider confidence intervals, key prevalence estimates remained robust, with margins of error ranging from ±4.6% to ±8.2%.

Data Collection Instruments and Procedures

Structured Questionnaire: A semi-structured, pre-tested questionnaire was administered to capture socio-demographic characteristics, household economic status, dietary diversity (using the Household Dietary Diversity

Score; FAO, 2011), WASH conditions, child health practices, and immunization status.

Anthropometric Measurements: Weight was measured to the nearest 0.1 kg using a SECA 874 digital scale. Recumbent length (for children under 24 months) or standing height (for older children) was recorded to the nearest 0.1 cm using a SECA infantometer or stadiometer, respectively. Mid-upper arm circumference (MUAC) was measured using a non-stretchable UNICEF tape. Weight-for-age Z-scores (WAZ) were calculated using WHO Anthro software (version 3.2.2). Underweight was defined as WAZ < -2 standard deviations (SD) below the WHO reference population median (WHO, 2006).

Blood Sample Collection and Biomarker Analysis: Venous blood samples were collected and analyzed for prealbumin, CRP, serum retinol, hemoglobin, albumin, and zinc. Biomarker thresholds followed international standards: vitamin A deficiency was defined as serum retinol <0.70 μmol/L; zinc deficiency as serum zinc <70 μg/dL; anemia as hemoglobin <11.0 g/dL; and elevated CRP as >3 mg/L. To account for confounding by inflammation, serum retinol and zinc values were adjusted using the Biomarkers Reflecting Inflammation and Nutritional Determinants of Anemia (BRINDA) internal regression correction method (Namaste *et al.,* 2017).

Data Analysis

Data analysis was performed using IBM SPSS version 26 and STATA version 18.0. Descriptive statistics (frequencies, means, and standard deviations) summarized all variables. Bivariate analysis employed chi-square tests for categorical variables and t-tests for continuous variables. Multivariable binary logistic regression identified independent predictors of underweight (WAZ < -2SD). Variables with $p < 0.25$ in bivariate analysis and those of known biological importance were entered into the initial model. Backward stepwise elimination was used to derive the final model. Adjusted odds ratios (AOR) with 95% confidence intervals (CI) were calculated. Model fit was assessed using the Hosmer-Lemeshow test ($p > 0.05$ indicating good fit) and Nagelkerke R^2.

Ethical Considerations

Ethical approval for this study was obtained from the Health Research Ethics Committee of the Sokoto State Ministry of Health (Reference Number: SKHREC/059/2022). Written informed consent was obtained from all participating mothers or caregivers. Children identified with severe acute malnutrition during the study were immediately referred to appropriate healthcare facilities for management.

RESULTS AND DISCUSSION

Demographic and Socioeconomic Characteristics

The study cohort comprised 150 children with a mean age of 30.2 months (standard deviation ± 16.8 months; age range: 6–59 months). The majority of participants resided in rural areas (82% of the sample). Monthly household income was critically low: 80% of households survived on less than ₦50,000 per month, and 45.3% earned less than ₦20,000 monthly. Educational attainment among caregivers was low: only 10% had attained tertiary education, while 19.3% had no formal education or only Qur'anic education.

Household Food Security and Dietary Diversity

Household food insecurity was pervasive. Specifically, 64.7% of households reported being unable to access a balanced meal for three or more days per week. Dietary diversity was critically low: 73.3% of households consumed four or fewer food groups, and only 4.7% achieved high dietary diversity (seven or more food groups).

Anthropometric Prevalence of Malnutrition

The prevalence of underweight (WAZ < -2SD) was 83.3% (95% CI: 76.5–88.6), with 20.0% of children severely underweight (WAZ ≤ -4SD). MUAC classification revealed that 68.7% of children suffered from acute malnutrition, including 28.0% with Severe Acute Malnutrition (SAM; MUAC < 11.5 cm) and 40.7% with Moderate Acute Malnutrition (MAM; MUAC 11.5–12.5 cm). Only 31.3% were classified as normal by MUAC (>12.5 cm).

Biochemical Profile and Micronutrient Deficiencies

Table 1 presents the biochemical profile of the study participants. Protein-energy malnutrition was confirmed by critically low mean prealbumin (6.8 ± 2.1 mg/dL) and serum albumin (3.1 ± 0.5 g/dL). Micronutrient deficiencies were catastrophic: vitamin A deficiency affected 91.3% (95% CI: 86.7–95.9), zinc deficiency affected 73.3% (95% CI: 66.2–80.4), and anemia affected 78.7% (95% CI: 72.1–85.3).

Table 1: Biochemical Nutritional Status of Under-Five Children (N=150)

Biomarker	Unit	Normal Range	Study Mean ± SD (Range)	% Outside Normal Range	Clinical Interpretation
Prealbumin	mg/dL	16–35	6.8 ± 2.1 (3.0–21.6)	89.3% (Low)	Severe protein-energy malnutrition
C-Reactive Protein (CRP)	mg/L	<3	5.8 ± 2.3 (1.4–23.6)	78.0% (Elevated)	Widespread systemic inflammation
Serum Retinol (Vitamin A)	μmol/L	≥1.05	0.61 ± 0.22 (0.14–0.99)	91.3% (Deficient)	Critical public health level of VAD

Hemoglobin	g/dL	>11	9.3 ± 1.2 (5.8–12.4)	78.7% (Anemic)	Severe anemia prevalent
Serum Albumin	g/dL	>3.5	3.1 ± 0.5 (1.8–4.2)	64.0% (Low)	Chronic protein deficiency/inflammation
Serum Zinc	μg/dL	>70	61.4 ± 8.2 (42–89)	73.3% (Deficient)	High prevalence of zinc deficiency

Source: Author's analysis using study data (2025).

Systemic Inflammation: Dose-Response Relationship
Systemic inflammation was widespread, with 78.0% (95% CI: 71.3–84.7) of children exhibiting elevated CRP (>3 mg/L). A striking dose-response relationship emerged between MUAC category and CRP prevalence: rates increased progressively from normal (51.1%) to moderate acute malnutrition (MAM, 78.7%) to severe acute malnutrition (SAM, 92.9%) (χ^2 trend = 19.34, $p < 0.001$) (Figure 1). Specifically, the proportion of children with elevated C-reactive protein rose stepwise with worsening nutritional status: 51.1% among those with normal MUAC (>12.5 cm), 78.7% among those with MAM (MUAC 11.5–12.5 cm), and 92.9% among those with SAM (MUAC <11.5 cm). A significant linear trend was confirmed (χ^2 trend = 19.34, $p < 0.001$). **p < 0.01, ***p < 0.001 versus normal group.

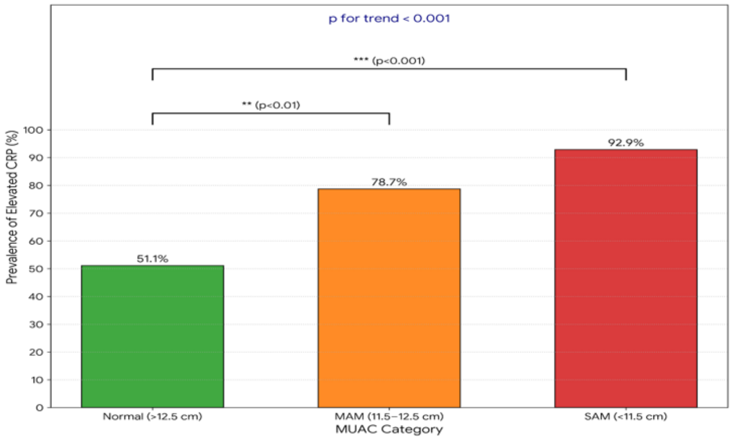

Figure 1:
Source: Author's analysis using study data (2025).

The Hidden Hunger Crisis
Critically, even among children classified as "normal" by MUAC (>12.5 cm), a substantial burden of hidden hunger was evident (Table 2). Among these 47 apparently well-nourished children: 72.3% were vitamin A deficient; 46.8% were anemic; 38.3% were zinc deficient; 51.1% had elevated CRP; and 38.3% exhibited three or more concurrent deficiencies.

Table 2: Prevalence of Biochemical Deficiencies by MUAC Category

Biomarker Deficiency	**Normal (MUAC >12.5 cm) (n=47)**	**MAM (MUAC 11.5–12.5 cm) (n=61)**	**SAM (MUAC <11.5 cm) (n=42)**	**χ^2 trend**	**p-value**
Vitamin A Deficiency (<0.70 μmol/L)	34 (72.3%)	58 (95.1%)	42 (100%)	18.42	<0.001
Severe Vitamin A Deficiency (<0.35 μmol/L)	4 (8.5%)	18 (29.5%)	20 (47.6%)	15.67	<0.001
Zinc Deficiency (<70 μg/dL)	18 (38.3%)	48 (78.7%)	40 (95.2%)	32.15	<0.001
Anemia (Hb <11.0 g/dL)	22 (46.8%)	52 (85.2%)	41 (97.6%)	28.63	<0.001
Elevated CRP (>3 mg/L)	24 (51.1%)	48 (78.7%)	39 (92.9%)	19.34	<0.001
Multiple Deficiencies (≥3 concurrent)	18 (38.3%)	52 (85.2%)	42 (100%)	41.23	<0.001

Source: Author's analysis using study data (2025).

Multiple Concurrent Deficiencies

Overall, 98.7% (n=148) of children suffered from at least one micronutrient or protein deficiency, and 78.7% (n=118) suffered from three or more concurrent deficiencies (Table 3). Only 1.3% (n=2) had no deficiencies.

Table 3: Prevalence of Biochemical Deficiencies by MUAC Category

Number of Deficiencies	Frequency (n)	Percentage (%)	Cumulative Percentage (%)
0 (No deficiency)	2	1.3	1.3
1 deficiency	8	5.3	6.6
2 deficiencies	22	14.7	21.3
3 deficiencies	45	30.0	51.3
4 deficiencies	58	38.7	90.0
5 deficiencies	15	10.0	100.0
Total	150	100	

Deficiencies assessed: vitamin A, zinc, anemia, prealbumin, and albumin.
Source: Author's analysis using study data (2025).

Multivariable Analysis: Independent Predictors of Malnutrition

Multivariable binary logistic regression identified three independent predictors of underweight (Table 4, Figure 2). The final model explained 41% of the variance (Nagelkerke $R^2 = 0.41$), and the Hosmer-Lemeshow test indicated good model fit ($\chi^2 = 8.9$, $p = 0.342$).

Table 4: Multivariable Logistic Regression of Factors Associated with Underweight (N=150)

Variable	Category	Frequency n (%)	AOR	95% CI	p-value
Household Dietary Diversity Score	Low (≤4 food groups)	110 (73.3%)	4.2	1.8–9.8	0.001
	Adequate/High (≥5 food groups)	40 (26.7%)	1.00	Reference	
Maternal Education	None / Qur'anic only	29 (19.3%)	3.1	1.3–7.4	0.011
	Primary	45 (30.0%)	2.1	0.9–5.1	0.089
	Secondary and above	76 (50.7%)	1.00	Reference	
Household Monthly Income	< ₦20,000 (Extreme Poverty)	68 (45.3%)	2.8	1.2–6.5	0.018
	₦20,000–₦50,000	52 (34.7%)	1.6	0.7–3.8	0.261
	> ₦50,000	30 (20.0%)	1.00	Reference	

Source: Author's analysis using study data (2025).
Note: Dependent variable: Underweight (WAZ < -2SD) = 1, Normal (WAZ ≥ -2SD) = 0. Model adjusted for child's age, sex, sanitation, immunization status, recent illness, distance to health facility, and breastfeeding practice.

Figure 2: Low household dietary diversity (≤4 food groups) was the strongest predictor (AOR = 4.2, 95% CI: 1.8–9.8), followed by low maternal education (none/ Qur'anic only; AOR = 3.1, 95% CI: 1.3–7.4), and extreme household poverty (<₦20,000/month; AOR = 2.8, 95% CI: 1.2–6.5). The vertical dashed line at AOR = 1 represents the null effect. Horizontal lines represent 95% confidence intervals. Marker size is proportional to the magnitude of the AOR.

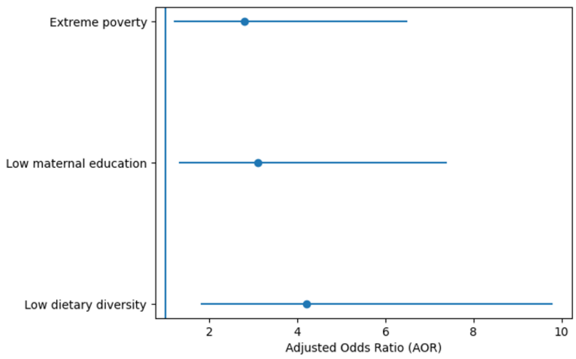

Figure 2: Forest plot of predictors of malnutrition
Source: Author's analysis using study data (2025).

Discussion

This study provides robust evidence that the malnutrition crisis in Sokoto State is driven by a powerful and synergistic interplay of three independent determinants: low household dietary diversity (AOR = 4.2), low maternal education (AOR = 3.1), and extreme household poverty (AOR = 2.8). These findings move beyond descriptive epidemiology to identify specific, quantifiable targets for intervention.

The finding that low dietary diversity was the strongest predictor even after controlling for poverty and education aligns with global evidence that diet quality, not merely caloric intake, is the critical determinant of child nutritional status (Arimond & Ruel, 2004; Ruel & Alderman, 2013). The observation that 73.3% of households consumed four or fewer food groups reflects a monotonous, cereal-based diet with minimal animal-source foods, fruits, or vegetables. This dietary pattern directly explains the near-universal prevalence of vitamin A deficiency (91.3%), zinc deficiency (73.3%), and anemia (78.7%) documented in this study.

The persistent effect of maternal education (AOR = 3.1) after controlling for poverty confirms that knowledge, literacy, and empowerment function as independent drivers of child nutrition (Smith *et al.,* 2003; Cleland & van Ginneken, 1988). In Sokoto State, where only 10% of caregivers have tertiary education, the pathways linking low maternal education to poor child nutrition include limited health literacy, reduced decision-making power within households, and lower economic autonomy (Glewwe, 1999).

Perhaps the most alarming finding is the high prevalence of biochemical deficiencies among children classified as "normal" by MUAC: 72.3% were vitamin A deficient, 46.8% were anemic, and 38.3% had three or more concurrent deficiencies. This reveals a massive burden of hidden hunger that remains invisible to conventional anthropometric screening (Muthayya *et al.,* 2013). The implication is clear: reliance on anthropometry alone will miss the majority of children with micronutrient deficiencies, and interventions targeting only visibly malnourished children will fail to address the broader crisis.

The finding that 78.0% of children have elevated CRP, with a dose-response relationship from normal (51.1%) to SAM (92.9%), confirms that infection and inflammation are integral components of the malnutrition syndrome (Scrimshaw & SanGiovanni, 1997). The syndemic framework "the synergistic interaction of co-occurring diseases and social conditions" (Singer & Clair, 2003) provides the most appropriate conceptual model for understanding this crisis, as it captures the mutually reinforcing relationships among protein-energy malnutrition, multiple micronutrient deficiencies, and systemic inflammation.

Strengths and Limitations

Strengths of this study include the integrated approach combining comprehensive anthropometry with a robust panel of biochemical markers, formal inflammation adjustment using BRINDA methods, and multivariable analysis to identify independent predictors of malnutrition.

Limitations Include

(1) the cross-sectional design precludes establishing causal relationships; (2) the final sample size of 150, while smaller than the calculated target of 643, was sufficient to detect the large effect sizes observed for the primary predictors (AORs ranging from 2.8 to 4.2), though it limited statistical power for smaller, clinically plausible risk factors; (3) recruitment from PHC attendees may introduce selection bias toward children already in contact with the health system; and (4) findings may not be generalizable to children who do not access health services.

CONCLUSION

Principal Findings

This study provides irrefutable evidence that childhood malnutrition in Sokoto State is driven by a synergistic interplay of three independent determinants: low dietary diversity (AOR = 4.2), low maternal education (AOR = 3.1), and extreme poverty (AOR = 2.8). The near-universal prevalence of vitamin A deficiency (91.3%), zinc deficiency (73.3%), anemia (78.7%), and systemic inflammation (78.0%) demonstrates that children are physiologically depleted at the molecular level. Critically, the high burden of hidden hunger among anthropometrically "normal" children reveals that sole reliance on anthropometry misses the majority of micronutrient deficiencies.

Recommendations

First, prioritize dietary diversity as the central programmatic goal. Interventions must move beyond calorie-centric approaches to focus on diet quality through homestead food production, biofortified crops, and social protection programs that enable the purchase of diverse foods.

Second, invest in girls' education as a foundational nutrition intervention. Policies to keep girls in school through the secondary level, integration of nutrition education into school curricula, and community-based adult education for current mothers are essential.

Third, implement multi-sectoral poverty alleviation strategies. Strengthen social protection with predictable cash transfers, promote livelihood diversification, and improve market access through rural infrastructure investment.

Fourth, integrate nutrition and infection control. Routine deworming, malaria chemoprevention, active promotion of vaccination, and integrated community case management (iCCM) that combines infection treatment with nutritional assessment are required.

Fifth, address the WASH-nutrition nexus. Scale up community-led total sanitation to eliminate open defecation, promote point-of-use water treatment, and integrate handwashing promotion into all nutrition contacts.

Sixth, integrate biochemical assessment into nutritional surveillance. Point-of-care hemoglobin testing, periodic biochemical assessments at sentinel sites, and point-of-care CRP testing to differentiate primary malnutrition from infection-related wasting are needed.

5.3 Concluding Statement

The children of Sokoto State face a nutritional syndemic of exceptional severity, protein-energy malnutrition, multiple micronutrient deficiencies, and chronic inflammation that systematically compromises their survival, growth, and development. The evidence leaves no room for complacency. The high prevalence of hidden hunger among anthropometrically normal children reveals that the true burden is substantially higher than conventional screening indicates. The cost of inaction in child deaths, impaired cognitive development, reduced educational attainment, and diminished lifetime productivity far exceeds the investment required for evidence-based interventions. The time for action is now.

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