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Research Article

Assessment of Micronutrient Deficiencies Among Children Under Five in Selected Urban and Rural Areas of Birnin Kebbi Local Government Area, Kebbi State, Nigeria

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ABSTRACT
Micronutrient deficiencies, termed "hidden hunger," pose significant public health challenges, particularly among children under five in developing regions. This study assessed the prevalence, determinants, and socio-economic factors associated with micronutrient deficiencies (iron, zinc, calcium, vitamin A) among 120 children under five in selected urban and rural areas of Birnin Kebbi Local Government Area (LGA), Nigeria. A cross-sectional design was employed, utilizing biochemical assays, anthropometric measurements, dietary assessments, and caregiver interviews. Results revealed higher deficiency rates in rural children (58% iron deficiency compared to 38% urban) and lower mean serum levels of iron (7.88µmol/L compared to 9.29µmol/L), zinc (6.09µmol/L compared to 8.15µmol/L), and calcium (1.10mmol/L compared to 1.13mmol/L). Rural children exhibited poorer anthropometric outcomes, including higher rates of severe stunting (20% compared to 5%) and severe acute malnutrition (28% compared to 11.7% for the urban). Socio-economic factors, such as lower caregiver education ($p = 0.0000$), unemployment ($P < 0.0001$), and food insecurity ($P = 0.000238$) were significantly associated with deficiencies. Dietary diversity was lower in rural areas ($P = 0.009$), and caregiver awareness of micronutrients was notably limited (20% rural compared to 78% urban). These findings underscore the need for targeted interventions, including supplementation, nutrition education, and agricultural support, to address micronutrient deficiencies in rural settings. Longitudinal studies are recommended to establish causality and inform policy.

Keywords: Children under five; Dietary diversity; Food insecurity; Micronutrient deficiencies; Urban-rural disparities

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INTRODUCTION

Micronutrient deficiencies, popularly known as "hidden hunger," is a serious public health challenge worldwide, particularly among children under the age of five in developing countries (Kumar *et al*., 2021). A pooled analysis study conducted by Steven *et al*., (2024) revealed that approximately 56% of children globally suffer from a deficiency in at least one of the following micronutrients: iron, vitamin A, or zinc. This figure indicates an increase of about 6% when compared to the 2019 data by UNICEF which stated that 1 in every 2, that is, (50%) children suffer from micronutrient deficiencies. The 56%, which represents about 372 million children under the age of five aligns with the findings of a separate study by Passarelli *et al*., (2024), which stated that over half of preschool children aged 6 to 59 months are deficient in one or more micronutrients, particularly zinc, iron, or vitamin A.

In Nigeria, micronutrient malnutrition contributes largely to child morbidity and mortality with about 70% of children suffering from anaemia. Although the iron deficiency was reported to be relatively low (18%), Vitamin B9 (folate) deficiency stood relatively high (63%) which could justify the high level of anaemia (Federal Government of Nigeria and Institute of Tropical Agriculture, 2024). John *et al*., (2024) reported the prevalence of anaemia to be withing the range of 55.2 to 75.1% from the data drawn from six different states of the country stating that regional disparity exists, with higher rates of micronutrient malnutrition observed in the North compared to the South. Further, the prevalence of calcium, Zinc, Vitamin A, Vitamin C, Vitamin B1, Vitamin B9, among children aged 24 to 59 months was reported to be 92%, 3.5%, 12.4%, <5%, 32%, 63% respectively (Federal Government of Nigeria and Institute of Tropical Agriculture, 2024).

Micronutrients play crucial role in the growth and development such that their deficiencies could lead to a serious growth and developmental problems and/or irreversible damage to the body system. Several studies have demonstrated the negative impact of micronutrient malnutrition. A study conducted by Mwene-Batu, *et al*., (2020), for example, reported that malnutrition survivors had lower chances of attaining higher level of education, having self-esteem, reporting a high academic performance compared to community control. The study further reveals that the cognitive test score for malnutrition survivors came out lower compared to the control group proving the impact of malnutrition on mental soundness.

This study aimed to assess the prevalence, determinants, and socio-economic factors of micronutrient deficiencies (iron, zinc, calcium, vitamin A) among children under five in selected urban and rural areas of Birnin Kebbi Local Government Area (LGA), Kebbi State, to inform targeted interventions.

MATERIALS AND METHODS

Study Area

The study was conducted in three rural namely, Zauro, Ambursa and Maurida and three urban - Gwadangwaji, Takalau and Badariya - communities of Birnin Kebbi Local Government Area (LGA), Kebbi State, Nigeria. Kebbi State is located in the North-Western Nigeria between latitudes 10° 8'N - 13°5'N and longitude 3°30E - 6°02E with a population of 3,238,628 people according to 2006 National census. It has a land area of 36800 square kilometres and 21 local government areas. Majority of its indigenes are Hausa ethnic group with variety of other ethnic groups in the southern part of the state. Kebbi state is also characterized with tropical weather conditions of harmattan, dry season and rainy-season like other Nigerian states. It is predominantly rural, with many households relying on subsistence agricultural activities for their livelihood. Kebbi state was chosen as the study area because it is one of the states in Nigeria with reported high levels of malnourished children (Ezekannagha *et al*., 2024)

Study Design and Population

A cross-sectional study was conducted in selected areas of Birnin Kebbi LGA, Kebbi State, Nigeria. The study population comprised 120 children aged 6–59 months, with 60 from urban and 60 from rural areas and their corresponding caregivers, selected through multistage sampling. Apparently healthy children aged 6–59 months domiciled in Birnin Kebbi were included, while children with chronic illnesses, recent micronutrient supplementation, and visitors to Birnin Kebbi were excluded.

Sample Size and Sampling Technique

The sample size for this study was determined using Cochran's formula for calculating sample size for a cross-sectional study (Nanjundeswaraswamy and Divakar, 2021). A margin of error of 5%, and a confidence level of 95%, 120 sample size was used for the study.

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

Where:

Z = Standard normal deviation (1.96 at 95% confidence level)

P = Estimated prevalence of micronutrient deficiencies (50% assumed in the absence of prior data)

d = Precision (0.05)

The sampling technique was based on random collection of samples from the children at the selected location.

Ethical Approval

Ethical approval was obtained from the Kebbi State Ministry of Health with reference number **MOH/KSREC/VOL.1/56.** Informed consent was obtained from caregivers before data collection through the informed consent form. Participants were assured of confidentiality and data generated were coded to disconnect participants' information from it.

Chemicals and Reagents

All the chemicals and reagents used in this study were of analytical grade. All from Randox

Laboratories, Northern Ireland, Sigma-Aldrich Chemie GmbH, Germany, and Cyman chemicals, USA.

Data Collection Instruments

Socio-economic and demographics, awareness and knowledge of micronutrients assessment, and food security assessment data were collected through structured questionnaires. A 24-hour dietary recall was used to collect data on dietary patterns and micronutrient intake (Faber, *et al*., 2016)

Anthropometric Measurements

All the anthropometric measurements namely weights, heights, mid-upper-arm circumferences were determined using World Health Organization's Standard Protocols as described by Food and Nutrition Technical Assistance - FANTA (2018). The body mass indexes (BMI) of the participants were obtained by dividing the individual's weight in kilograms (kg) by the square of their height in meters (m) (Casadei and Kiel, 2022).

Biochemical Analysis

Blood samples collected were analysed for serum levels of total protein using the Lowry's method as described by Aliaksandr (2019); iron, calcium, and zinc were measured using Atomic Absorption Spectrophotometry, AAS (Buck Scientific Atomic Absorption Emission Spectrophotometer model 205, manufactured by Norwalk, Connecticut, USA). Vitamin A (serum retinol) levels were determined through a spectrophotometric method (Model 6800, Shimadzu, Japan) as described by Igharo and Idomeh (2020).

Data Analysis

Data were analysed using Excel software (version 2002). Descriptive statistics (means, standard deviations, percentages) summarized prevalence and nutrient levels. Chi-square tests assessed associations between socio-demographic factors and deficiency status between urban and rural groups. A p-value < 0.05 was considered statistically significant.

RESULTS

Socio-Demographic Characteristics and Their Association with Micronutrient Deficiency

The socio-demographic characteristics of the study participants in selected urban and rural areas of Birnin Kebbi Local Government and their association with micronutrient deficiencies are presented in table 1-3. A total number of 120 participants were recruited for the study, 60 from urban areas and 60 from rural areas. Location (urban/rural) showed strong association with iron and vitamin A deficiencies (p-values 0.0284, 0.0059 respectively); level of education is connected with iron and zinc deficiencies (p-values: 0.0000, 0.0002 respectively); occupation has shown strong association with iron and zinc deficiencies (p-values: 0.0000 0.0062 respectively). The average number of under five children in rural areas (3±1.5) is shown to be higher than urban settings (2.8 ± 1.6). Average caregiver's age is lower in rural area (29.8 ± 6.5) compared the urban area (32.8 ± 7.5) while the average household size for both locations are almost the same.

Dietary Patterns and Micronutrient Intake of Children Under Five in The Study Areas

The results for foods consumed within the last 24 hours and dietary diversity score for the children under five in selected rural and urban areas of Birnin Kebbi are presented on table 4-5. Higher percentage of children residing in urban areas consume more foods rich in micronutrients compared to those dwelling in rural areas with an average serving of vegetables 1.5 and 1 per day respectively and animal protein 2 and 1 servings per day respectively. Children in urban areas have high dietary diversity score compared to the children in rural children with about 52% of the children in urban area consuming greater than 5 food groups per day compared to 17% for those in the rural areas.

Awareness and Knowledge of Micronutrient Deficiencies Among Caregivers

Knowledge and awareness of micronutrient deficiencies and their prevention among the care givers are presented in table 6. There is high level of awareness of micronutrient deficiency among the care givers in urban area with only about 22% being not aware compared to 80% of the participants from the rural area who are not aware of micronutrient deficiency. The chi-square test reveals high association between knowledge and awareness of micronutrient deficiencies and location (P-value: 0.0000). About 87% of the caregivers from the rural area doesn't know micronutrient rich foods compared to care givers from urban area which has 53%.

Household Food Insecurity Among Caregivers of Children Under Five in Urban and Rural Study Areas

Table 7 presents the results of food insecurity indicators among the caregivers of children under five in urban and rural areas. The results showed high food insecurity in both areas with the rural area suffering from the higher impact - 62% caregivers running out of food before having money to buy - compared to urban which has 43% caregivers experiencing food shortage. Chi-square test reveals high association between this indicator and location (P-value: 0.000238). About 33% of children in rural settings often skip meals because there is no enough compared to 17% for the urban area. Strong association also exists between this indicator and location (p-value: 0.021782).

Anthropometric Measurements

The anthropometric measurements which include Mid-upper-arm circumference, weight, height and body mass index (BMI) are presented in table 8-11. The mid-upper-arm circumference results reveal higher severe acute malnutrition (SAM) in rural area (28%) compared to urban area (11.7%). Weight-for-age shows 31.7% of severe underweight in rural area and 18.3% in urban area. Height-for-age showed 20% and 5% severe stunting in rural and urban areas respectively.

Micronutrient Levels

The mean nutrient levels are presented in table 12. The average total protein levels of the under five children in both urban (7.10g/dL) and rural (6.93g/dL) areas are within the normal range of 6 to 8g/dL (Gregory and Andropoulos, 2012). The sample mean for vitamin A also fall above the deficiency value of ≥ 0.70 µmol/L for both areas. The sample mean of serum iron for urban (9.29 µmol/L) and rural (7.88 µmol/L) areas are within the normal range of 7-26 µmol/L (Gregory and Andropoulos, 2012) but sample average for zinc for the under five children in both urban (8.15 µmol/L) and rural (6.09 µmol/L) areas are below normal (> 10 µmol/L). The mean total calcium levels for both urban (1.13mmol/L) and rural (1.10mmol/L) areas are below the normal range of 2.00 – 2.70 mmol/L (Gregory and Andropoulos, 2012).

Table 1: Association Between Socio-Demographic Characteristics of Caregivers and Households and Iron/Vitamin A Deficiency Among Children Under Five in the Study Area

Variables (caregivers)	Category	Iron Deficiency n (%)	Total	P- value	Vitamin A Deficiency n (%)	Total	P- value
Location	Urban	23(38)	60	0.0284	4(7)	60	0.0059
	Rural	35(58)	60		15(25)	60	
Education level	No formal education	37(88)	42	0.0000	9(21)	42	0.1006
	Primary	12(67)	18		5(28)	18	
	Secondary	7(15)	48		3(6)	48	
	Tertiary	2(17)	12		2(17)	12	
Occupation	Employed	12(24)	49		7(14)	49	0.6975
	Unemployed	46(65)	71	0.0000	12(17)	71	
House-hold Income	N10,000-N30,000	43(57)	76		11(14)	76	
	N30,000-N50,000	11(37)	30	0.0526	7(23)	30	0.3592
	N50,000+	4(29)	14		1(7)	14	

Values represent the number (n) and percentage (%) of children with the specified deficiency. Statistical significance was assessed using chi-square tests, with p-values < 0.05 considered significant

Table 2: **Association Between Socio-Demographic Characteristics of Caregivers and Households and Zinc/ Calcium Deficiency Among Children Under Five in the Study Area**

Variables (caregivers)	Category	Zinc Deficiency n (%)	Total	P- value	Calcium Deficiency n (%)	Total	P- value
Location	Urban	34(57)	60	0.066	18(30)	60	0.052
	Rural	43(72)	60		29(48)	60	
Education level	No formal educ.	39(93)	42		22(52)	42	
	Primary	13(72)	18	0.0002	10(55)	18	
	Secondary	20(42)	48		10(55)	48	0.710
	Tertiary	5(42)	12		5(42)	12	
Occupation	Employed	24(49)	49	0.0062	14(29)	49	0.095
	Unemployed	53(75)	71		33(46)	71	
	10,000-30,000	48(70)	76		25(33)	76	
House-hold	30,000-50,000	21(70)	30	0.927	14(47)	30	0.199
Income	50,000+	8(57)	14		8(57)	14	

Variables are represented as numbers (n) and percentages (%) of children with the specified deficiency

Statistical significance was assessed using chi-square tests, with p-values < 0.05 considered significant

Table 3: Average Caregivers' Age, Household Size and Number of Under Five Children

Variables	Urban (n=60)	Rural (n=60)	Overall (n=120)
Caregiver's Age mean (SD)	32.8 ± 7.5	29.8 ± 6.5	31.3 ± 7.1
Household Size mean (SD)	10.8 ± 4.3	10.6 ± 3.4	10.7 ± 3.9
No. of under 5 mean (SD)	2.8 ± 1.6	3.2 ± 1.5	3.0 ± 1.5

Variables are reported as means ± standard deviations (SD)

Table 4: **Consumption of Food Groups and Average Servings Among Children Under Five in Urban and Rural Study Areas in the Last 24 Hours**

Food Groups	**Urban n (%)**	**Avg. Servings**	**Rural n (%)**	**Avg. Servings**
Grains & Cereals	60(100)	3 servings	60(100)	3 servings
Vegetables	31(52)	1.5 servings	22(37)	1 serving
Fruits	23(38)	1 serving	10(17)	1 serving
Legumes & Nuts	15(25)	1 serving	17(28)	1 serving
Dairy Products	11(18)	1 serving	7(12)	1 serving
Animal Protein	26(43)	2 servings	15(25)	1 serving

The number (n) and percentage (%) of children consuming each food group are reported, alongside the average servings per day for those who consumed each group. Percentages reflect the proportion of children in each location consuming at least one serving of the specified food group daily. Data were derived from 24-hour dietary recall

Table 5: Dietary Diversity Score (DDS) Distribution Among Children Under Five

Category	**Urbans n (%)**	**Rural n (%)**	**P-value**
<3 Food Groups	0(0)	0(0)	
3-5 Food Groups	29(48)	43(72)	0.009*
>5 Food Groups	31(52)	17(28)	

Data are presented as the number and percentage (n (%)) of children in each category for Urban and rural. The p-value, indicates a statistically significant difference in DDS distribution between Urban and Rural ($p < 0.05$)

Table 6: Awareness and Knowledge of Micronutrient Deficiencies and Their Prevention Among Caregivers

Variable	**Category**	**Urban n (%)**	**Rural n (%)**	**P-value**
Have heard of micronutrient deficiency	Yes	47 (78%)	12 (20%)	0.0000*
	No	13 (22%)	48 (80%)	
Micronutrients familiar with	Iron	56 (93%)	21 (35%)	0.0134*
	Vitamin A	23 (38%)	11 (18%)	
	Folate	58 (97%)	33 (55%)	
	Zinc	21 (35%)	2 (3%)	
	Iodine	12 (20%)	0 (0%)	
	Others	5 (8%)	0 (0%)	
Causes of Micronutrient Deficiency (MND)	Poor diet	43 (72%)	12 (20%)	1.1228
	Inadequate breastfeeding	37 (62%)	16 (27%)	
	Poor sanitation	11 (18%)	0 (0%)	
	Illnesses	3 (5%)	0 (0%)	
Effects of MND on children	Stunted growth	27 (45%)	13 (22%)	0.0000*
	Weakened immune	14 (23%)	11 (18%)	
	Poor cognitive development	13 (22%)	0 (0%)	
	Delayed motor skills	15 (25%)	0 (0%)	
	Blindness	12 (20%)	5 (8%)	

Variable	Category	Urban n (%)	Rural n (%)	P-value
Knowledge of micronutrient-rich foods	Yes	28 (47%)	8 (13%)	0.0000*
	No	32 (53%)	52 (87%)	

Data are reported as frequencies and percentages (n (%)) based on caregiver responses through questionnaire. Multiple responses were allowed for micronutrients, causes, effects, and prevention methods, so percentages may exceed 100% within those categories. A P < 0.05 indicate statistical differences between Urban and Rural

Table 7: Household Food Insecurity Indicators Among Caregivers of Children Under Five in Urban and Rural Study Areas

Variable	Category	Urban n (%)	Rural n (%)	P- Value
Worry about not having enough food	Often	21 (35%)	33 (55%)	0.0841
	Sometimes	23 (38%)	17 (28%)	
	Never	16 (27%)	10 (17%)	
Ran out of food before having money to buy more	Often	26 (4 3%)	37 (62%)	0.0002*
	Sometimes	15 (25%)	21 (35%)	
	Never	19 (32%)	2 (3%)	
Adults skipped meals because there was not enough	Often	41 (68%)	35 (58%)	0.1351
	Sometimes	9 (15%)	18 (30%)	
	Never	10 (17%)	7 (12%)	
Children skipped meals because there was not enough	Often	10 (17%)	20 (33%)	0.0218*
	Sometimes	18 (30%)	22 (37%)	
	Never	32 (53%)	18 (30%)	
Adults ate less than they felt they should	Often	39 (65%)	30 (50%)	0.0795
	Sometimes	11 (18%)	22 (37%)	
	Never	10 (17%)	8 (13%)	
Went a whole day and night without food	Often	7 (12%)	14 (23%)	0.0038*
	Sometimes	13 (21%)	24 (40%)	
	Never	40 (67%)	22 (37%)	
Ate just a few kinds of food	Often	45 (75%)	41 (68%)	0.0185*
	Sometimes	10 (17%)	19 (32%)	
	Never	5 (8%)	0 (0%)	
Ate food they really did not want	Often	46 (77%)	50 (83%)	0.5397
	Sometimes	8 (13%)	7 (12%)	
	Never	6 (10%)	3 (5%)	

Data are reported as frequencies (n) and percentages (%) within each location, based on caregiver responses from questionnaire. P-values, derived from chi-square tests, assess differences in distributions between Urban and Rural, with statistical significance indicated by * ($p < 0.05$)

Table 8: Nutritional Status Comparison Between Urban and Rural (Mid-Upper-Arm-Circumference - MUAC)

Nutritional Status	Urban n (%)	Rural n (%)	P-value
Severe Acute Malnutrition (SAM)	7 (11.7%)	17 (28%)	0.032444*
Moderate Acute Malnutrition (MAM)	10 (16.7%)	12 (20.0%)	
Normal	43 (71.6%)	31 (52%)	

Categories are defined as Severe Acute Malnutrition (SAM, $Z < -3$), Moderate Acute Malnutrition (MAM, $-3 \le Z < -2$), and Normal ($Z \ge -2$). Percentages are calculated as the proportion of children in each category within each location. Data were derived from anthropometric measurements of MUAC

Table 9: Nutritional Status Comparison Between Urban and Rural (Weight-For-Age)

Nutritional Status	Urban n (%)	Rural n (%)	P-Value
Severe Underweight	11 (18.3%)	19 (31.7%)	
Moderate Underweight	10 (16.7%)	15 (25%)	0.056888
Normal	39 (65%)	26 (43.3%)	

Categories are defined as Severe Underweight (Z < -3), Moderate Underweight (-3 ≤ Z < -2), and Normal (Z ≥ -2). Percentages are calculated as the proportion of children in each category within each location. Data were derived from anthropometric measurements of weight. P < 0.05

Table 10: Nutritional Status Comparison Between Urban and Rural (Height-For-Age)

Nutritional Status	Urban n (%)	Rural n (%)	P-value
Severe Stunting	3 (5.0%)	12 (20%)	
Moderate Stunting	10 (16.7%)	9 (15.0%)	0.045121*
Normal	47 (78.3%)	39 (65%)	

Categories are defined as Severe Stunting (Z < -3), Moderate Stunting (-3 ≤ Z < -2), and Normal (Z ≥ -2). Percentages are calculated as the proportion of children in each category within each location. Data were derived from anthropometric measurements of height

Table 11: Nutritional Status Comparison Between Urban and Rural (Body Mass Index - BMI)

Nutritional Status	Urban n (%)	Rural n (%)	P-value
Severe Thinness	2 (3.3%)	5 (8.3%)	
Moderate Thinness	13 (21.7%)	26 (43.3%)	0.011745
Normal	39 (65%)	28 (46.7%)	
Overweight/Obese	6 (10.0%)	1 (1.7%)	

Categories are defined as Severe Thinness (Z < -3), Moderate Thinness (-3 ≤ Z < -2), Normal (-2 ≤ Z ≤ 1), and Overweight/Obese (Z > 1). Percentages are calculated as the proportion of children in each category within each location. Data were derived from anthropometric measurements of weight and height, with BMI calculated as weight (kg) / height² (m²)

Table 12: Mean Nutrient Levels Across Locations in Children Under Five

Location	Total Protein (g/dL)	Vitamin A (µmol/L)	Iron (µmol/L)	Zinc (µmol/L)	Calcium (mmol/L)
Urban	7.10 ± 0.76	1.37±0.23	9.29 ± 2.32	8.15 ± 0.26	1.13 ± 0.22
Rural	6.93 ± 0.09	1.35 ± 0.18	7.88 ± 1.95	6.09 ± 1.27	1.10 ± 0.19

This table shows mean nutrient levels (± SD) in children under five across locations.

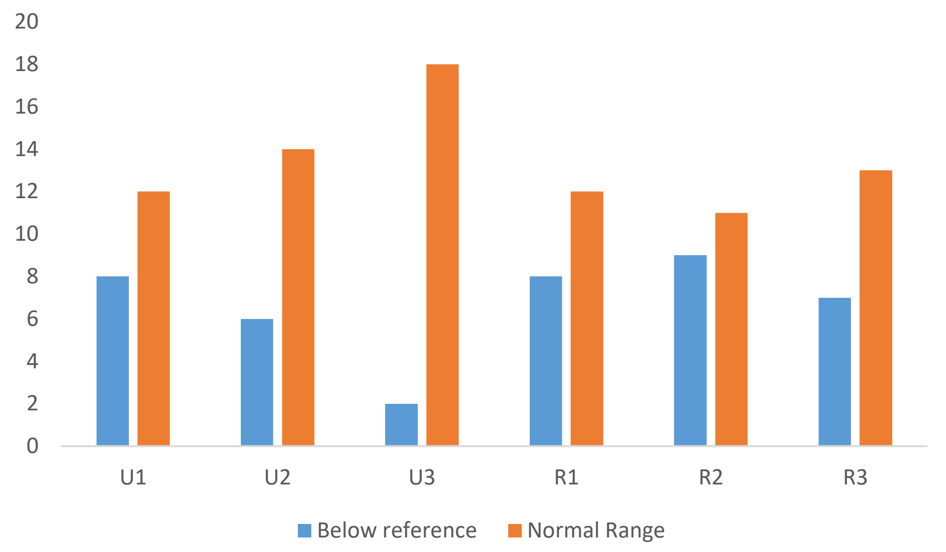

Figure 1: Total Serum Protein Levels Across the Selected Urban (U1, U2, U3) and Rural (R1, R2, R3) Locations in Birnin Kebbi LGA

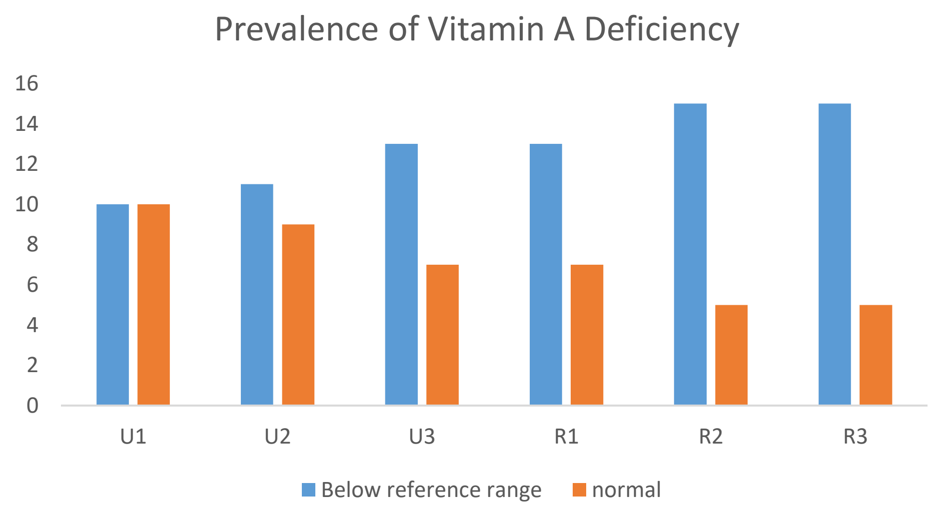

Figure 2: Vitamin A Deficiency Rates in Children Under Five Across the selected Urban (U1, U2, U3) and Rural (R1, R2, R3) Locations in Birnin Kebbi LGA

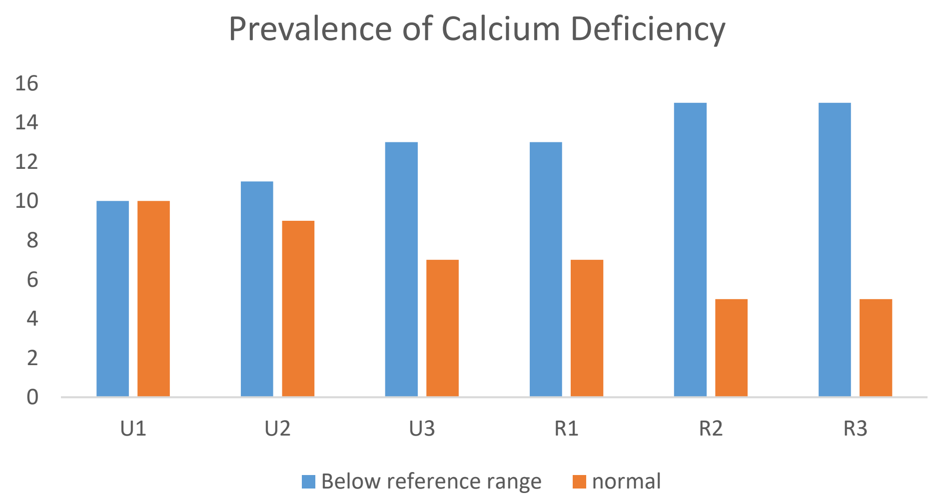

Figure 3: Calcium Deficiency Rates in Children Under Five Across Urban (U1, U2, U3) and Rural (R1, R2, R3) Locations in Birnin Kebbi LGA

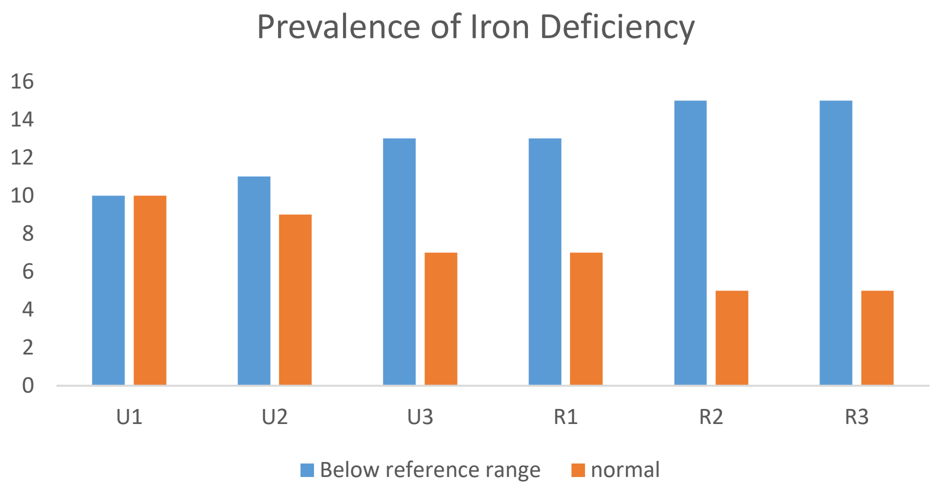

Figure 4: Prevalence of Iron Deficiency among Children Under Five Across Urban (U1, U2, U3) and Rural (R1, R2, R3) Locations in Birnin Kebbi LGA

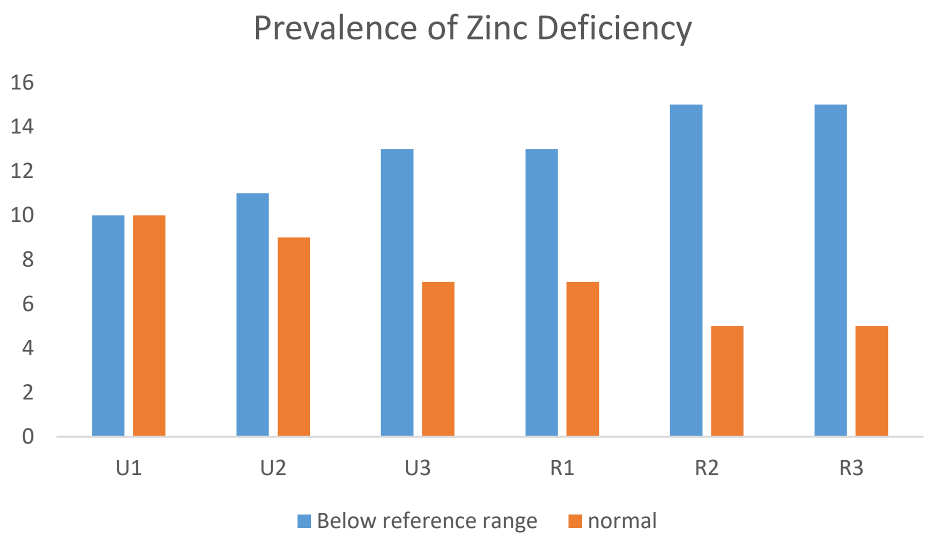

Figure 5: Zinc Deficiency Prevalence among Children Under Five in Urban (U1, U2, U3) and Rural (R1, R2, R3) Locations in Birnin Kebbi LGA

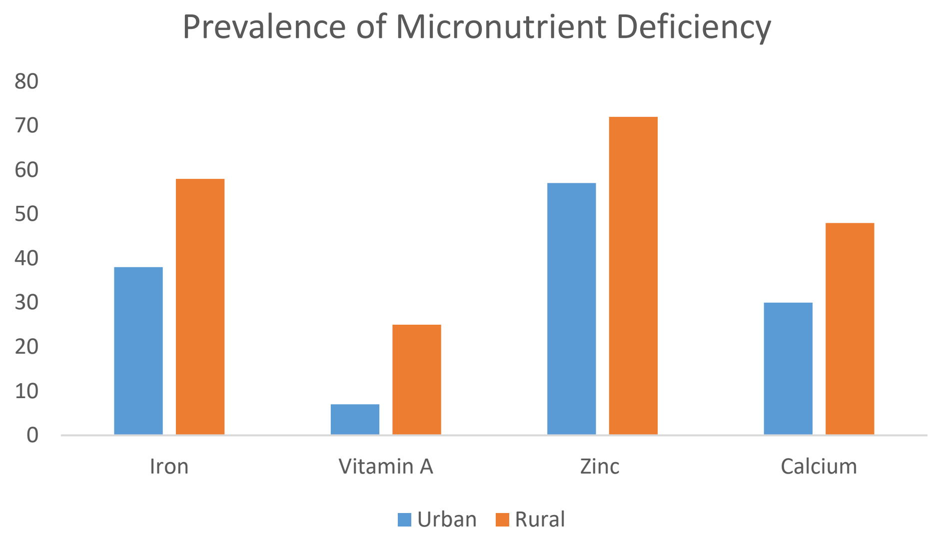

Figure 6: Prevalence of Micronutrient Deficiency Between Urban and Rural Location

DISCUSSION

This study highlights significant urban-rural disparities in micronutrient deficiencies among children under five in Birnin Kebbi LGA. Rural children facing a higher burden of iron, zinc, and calcium deficiencies. The prevalence of iron deficiency (58% rural compared to 38% for the urban) aligns with national estimates (55.2–75.1%) and underscores its role in anaemia (John *et al*., 2024). Zinc deficiency rates (72% rural compared to 57% for the urban) are consistent with global trends in sub-Saharan Africa, where inadequate dietary intake is a primary driver (Wessells and Brown 2012). Calcium deficiencies were alarmingly high in both groups. This could be due to low dairy consumption, a common issue in rural Nigeria (Ogunba and Adeyemi, 2015). The biochemical findings, showing lower serum iron, zinc, and calcium levels in rural children, reflect structural barriers such as limited dietary diversity. These results mirror studies in south eastern Nigeria, where rural children had lower nutrient status due to reduced access to animal-source foods (Ayogu *et al*. 2016). Vitamin A levels, however, were within normal ranges, likely due to national supplementation programs (National Population Commission and ICF, 2018).

Socio-economic factors, including low caregiver education and unemployment, were strongly associated with deficiencies, consistent with prior research linking maternal education and income to child nutrition (Smith and Hadad, 2015). The significant knowledge gap among rural caregivers (20% awareness compared to 78% urban) highlights the need for targeted nutrition education, as awareness is critical for adopting preventive practices (Nutrition International, 2024).

Anthropometric outcomes further underscore the nutritional disadvantage in rural areas, with higher rates of stunting and severe acute malnutrition. These findings align with national data showing elevated stunting in northern Nigeria (66.1%) and global trends in sub-Saharan Africa (Getachew *et al*., 2023; UNICEF, 2024). Food insecurity and low dietary diversity are key contributors, as rural households rely heavily on staple crops, limiting access to nutrient-rich foods (Ukonu *et al*., 2024).

Limitations include the cross-sectional design, which precludes causal inferences, and the focus on selected micronutrients, omitting others like iodine or selenium due to resource constraints. The study's regional scope may limit generalizability, though findings are consistent with broader Nigerian and sub-Saharan African trends.

Future research should employ longitudinal designs to establish causality and include multi-site studies to assess regional variations. Interventions should prioritize rural areas, integrating micronutrient supplementation, nutrition education, and agricultural support to enhance dietary diversity. Policy measures addressing poverty and healthcare access are critical to breaking the cycle of malnutrition.

CONCLUSION

This study reveals a higher burden of micronutrient deficiencies and poor nutritional outcomes among rural children under five in the selected areas of Birnin Kebbi LGA, driven by socio-economic challenges, food insecurity, and limited dietary diversity. These findings highlight the urgent need for targeted public health interventions to address "hidden hunger" and support Nigeria's progress toward eliminating micronutrient deficiency. By integrating health, education, and agricultural strategies, policymakers can improve child nutrition and well-being in Kebbi State and beyond.

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