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Spatial Distribution and Predictors of Co-occurrence of Anemia and Stunting among Under-five Children in Nigeria

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Anemia and stunting are serious public health problems among children in sub-Saharan Africa and Nigeria in particular. This paper examined the prevalence of co-occurrence of anemia and stunting (CAS) in rural and urban areas, identified predictors of CAS in rural and urban areas, analyzed the spatial pattern of CAS, identified the variables associated with the spatial variation of CAS and map the spatial distribution of CAS. Data from 2018 Nigerian Demographic and Health Survey, spatial statistical techniques, multivariable logistic regression and geographically weighted Poisson regression were employed. There was no significant differences between the observed and expected frequency of CAS. Prevalence of CAS varied spatially in rural/urban areas, states and zones. Children that were still breastfeeding, male, with low maternal educational level, living in North West zone and poor households have high risk of being anemic and stunted concurrently. Overall, children in poor households and those that experienced diarrhea were more likely to have co-occurrence of anemia and stunting in rural and urban areas. Nationally, prevalence of CAS exhibited a clustered pattern. Hotspots clustered in the North West zone while coldspots were mostly in the south. There was significant spatial variations in the relationships between CAS and the explanatory variables across the states. Health agencies and policymakers need to implement and strengthen nutrition-specific interventions particularly in high-risk areas.

Keywords: Aanemia, stunting growth, co-occurrence of anemia, spatial analysis, Nigeria

Introduction

Anemia is a serious public health problem globally (WHO, 2020). It is a condition in which the number of red blood cells and /or hemoglobin (Hb) concentration in the blood are lower than normal and insufficient to meet an individual's physiological needs (Chaparro *et al*., 2019). Anemia is caused by malaria, tuberculosis, HIV, intestinal parasitic infections-hookworm infestation, schistosomiasis, genetic disorder such as thalassemia and pernicious anemia, and deficiencies in Vitamin A, C, B_{12} and folic acid (WHO, 2020; Ross and Horton, 1998; Petry *et al*., 2016).

Iron deficiency anemia is present when Hb levels in an individual are below two standard deviations (-2SD) of the distribution mean for Hb in an otherwise normal population of the same gender and age who are living at the same altitude (WHO, 2020). Hemoglobin concentration is the most common method used to diagnose anemia. In children aged 6-59 months, the cut-off of Hb concentrations for anemia is < 110 g/L. This is further classified as severe (-70g/L), moderate (70-99g/L), and mild (100-109g/L) anemia (Chaparro and Suchdev, 2019).

Africa had the highest (60.2%) prevalence of anemia in children aged 6-59 months compared to the global prevalence rate of 39.8% (equivalent to 269 million children) in 2019 (WHO, 2021). Prevalence of anemia in under-five children (U5C) in Nigeria was 68.3% and 67.9% in 2016 and 2018 respectively (NPC and ICF, 2019; World Bank, 2021). Anemia impacts the health and development of U5C through delay in psychomotor development and impairment of cognitive performance (Carter *et al*., 2010), increase risk for infectious diseases such as diarrhea and respiratory disease (Levy, 2005), and increase the risk of heavy-metal poisoning such as lead and cadmium (Hegazy *et al*., 2010).

Malnutrition denotes deficiencies, excesses or imbalance in intake of energy and/or essential nutrients or impaired nutrient utilization (WHO, 2020). Two classifications of malnutrition are under-nutrition and micronutrient–related malnutrition, and overweight, obesity and diet-related non-communicable diseases including heart disease, stroke, and diabetes (WHO, 2020). Under-nutrition occurs in U5C in the form of stunting or shortness, wasting or thinness, underweight and micro-nutrient deficiencies (lack of vitamins and minerals particularly iron, zinc, vitamin A and iodine).

Although under-nutrition can be prevented during the period from pregnancy to first two years of life (first 1000 days), the number of stunted, wasted, and overweight U5C globally was 149.0 million (21.9%), 49.5 million (7.3%) and 40.1 million (5.9%) respectively in 2018 (2020 Global Nutrition Report). By 2020, 149.2 million (22.0%) U5C were stunted (UNICEF, WHO and World Bank, 2021). Of these, the highest proportion (55.2%) were in sub-Saharan Africa. The prevalence of stunting in U5C in Nigeria declined from 48.7% in 1990 (Federal Office of Statistics, Nigeria and Institute for Resource Development, 1992), to 36.8% in 2018 (NPC and ICF, 2019) and 31.5% in 2020 (National Bureau of Statistics, 2018). However, the decline in stunting prevalence in Nigeria masks variations across states and socio-economic groups.

Given the association between stunting and child development and its impact on national development, the World Health Assembly endorsed stunting as a key indicator of infant and child nutrition in 2012 (United Nations Children's Fund Nigeria, 2015). Stunting which is a sign of chronic under-nutrition is assessed using the height-for-age measure. Stunting increase the risk of developmental and cognitive delay in children, infections (diarrhea, acute respiratory infection and malaria/fever) and mortality, cardiovascular disease in adulthood, impair socio-emotional, motor and cognitive development, lead to poor performance in school and reduced capacity to learn (Oot *et al*., 2016). Stunting also reduce national productivity as stunted children have the risk of losing about 10% of their lifetime earning potential, increase healthcare expenditure and exacerbate poverty (National Development Planning Commision, 2016).

In spite of the various government projects aimed at improving child nutrition such as the implementation of the National Strategic Plan of Action for Food and Nutrition (2014-2019), provision of ready-to-use therapeutic food, among other interventions (Awoyemi *et al*., 2012), the prevalence of stunting and anemia is still high in Nigeria. Consequently, Nigeria had the second highest under-five mortality rate (120 deaths per 1000 live births) globally in 2018 (WHO, 2019). Since severe anemia and stunting increase the risk of mortality in U5C, prevention of these conditions is critical if Nigeria is to achieve the Sustainable Development Goal target of reducing under-five mortality rate to 25 deaths per 1000 live births by 2030.

The conceptual framework on the causes of stunting and anemia as illustrated by UNICEF (2014) and Chaparro and Suchdev (2019) indicate that stunting and anemia are caused by similar factors such as inadequate dietary intake, infections and inadequate access to food. Therefore, identifying the existence of co-occurrence of anemia and stunting (CAS) could reduce the cost of implementation of interventions. Further, since health and ill-health have a spatial dimension (Kandwal *et al*., 2019), understanding the spatial dynamics of CAS will guide the design and implementation of targeted interventions that will improve child health.

Prior studies on CAS showed that there was no significant difference between the observed and expected frequency of co-occurrence of stunting and anemia in India and Peru (Gosdin *et al.*, 2018), Ghana (Christian *et al.*, 2020), Venezuela (Castejon *et al.*, 2004) and Honduras (Albalak *et al.*, 2000) so the two conditions should be treated independently. Several studies (Tran *et al*., 2018; Mohammed *et al*., 2019; Christian *et al*., 2020) indicate that environmental, individual and household socio-demographic and health factors are associated with CAS. However, findings from previous studies revealed that risk factors associated with CAS are context specific and inconclusive. For instance, Sahiledengle *et al.* (2003) found that the prevalence of CAS in Ethiopia was 24%. Children aged 12-23 months, 24-35 months and 6-59 months, with small size at birth, anemic mothers, mothers without education, those from households that practice open defecation, live in rural areas had higher odds of CAS. Tran *et al*. (2019) revealed that co-morbid anaemia and stunting among children aged 6-59 months was 21.5%. The risk of co-morbidity was higher in children living in rural areas, poorer households and have mothers with lower educational levels. Few studies (Haile *et al*., 2016; Christian *et al.*, 2020) have analyzed the spatial variation and clustering of stunting, anemia and co-occurrence of both conditions at district level or lower scales in the literature. In Nigeria, studies (Ayogu *et al.*, 2015; Samuel, 2013) have focused mainly on the predictors of anemia and stunting independently at local scales with limited national policy relevance. For instance, Ayogu *et al*. (2015) found that 85.5 % of the 450 school children examined in Nsukka, Enugu state were anemic.

Haemoglobin status of the children was influenced by parasitic infections, high birth order, large household size, frequent bouts of illnesses, skipping of breakfast, and low consumption of animal sources of iron. Amare *et al.* (2018) examined the determinants of stunting in Northeast and Northwest geopolitical zones of Nigeria. Significant differences in the determinants of undernutrition between the zones was observed. Studies (Gayawan *et al*., 2014; Gayawan *et al*., 2019a, 2019b; Magalhaes *et al*., 2011) that analyzed country-wide variation of anemia and stunting did not examine the spatial variation, urban-rural disparities and clustering of CAS among U5C. Gawayan *et al.* (2019b) examined the spatial distribution and relationships among indicators of childhood malnutrition and found a regional divide in the pattern of concentration of malnutrition in specific states. There is a North-South divide in the Hb concentration of children in Nigeria and children in Northern states have a higher risk of anaemia (Gawayan *et al.*, 2014). Understanding the factors associated with CAS in each residential area and across the 36 states and the Federal Capital Territory-Abuja (FCT) will guide the implementation of effective and targeted interventions in urban and rural areas.

This study uses data from the recent Nigeria Demographic Health Survey conducted in 2018 to 1) determine if the observed and expected frequency of CAS in urban and rural areas are different, 2) examine the individual and household characteristics that predict CAS in urban and rural areas, 3) analyze the spatial variation and clustering of CAS across the country, and 4) identify the variables associated with the spatial variation of CAS across the country and map their spatial distribution. Data on children aged 6-59 months was used to address the objectives.

Material and methods

The conceptual framework of the causes of stunting adapted from UNICEF's framework of under-nutrition (UNICEF, 2014) and the model of anemia etiology by Chaparro and Suchdev (2019) are used as the theoretical guide in this paper. The frameworks identify the interplay of immediate, underlying and basic causes of stunting and anemia in children.

Data

The data used in this study are from the recent Nigeria Demographic Health Survey (NDHS) conducted in 2018. The data are nationally representative cross-sectional samples of households in urban and rural areas located in the 36 states and FCT. Structured questionnaire was used to collect information on basic demographic and health indicators such as breastfeeding practices, nutritional status of women and children, maternal and child health at national, state and zonal levels. The stratified samples were selected using a two-stage cluster design.

Stratification was achieved by sorting the sample frame according to administrative order using a probability proportional to size selection. First, 1400 enumeration areas (clusters) were selected from the 2006 Population and Housing Census frame, then, 30 households were selected from each cluster through equal probability systematic sampling. Information was collected from women aged 15-49 years and men aged 15-59 years who were residents of selected households. Information on under-five children were obtained from their mothers/caregivers. A total of 40,427 households, 41,821 women and 13,311 men were interviewed representing a response rate of 99.4%, 99.3% and 99.2% respectively.

Anthropometry (height and weight) measurement of children and women were conducted by trained laboratory scientists and nurses. Using a Shorr Board measuring board, children aged less than 24 months were measured lying down while older children were measured standing up. SECA scales (Seca, Hamburg and Germany) was used for weight measurement. Haemoglobin testing was performed for children aged 6-59 months. A drop of blood from a finger prick (or heel prick for children aged 6-11 months) was obtained for anemia testing. A HemoCue$_{(g)}$ analyzer was used on-site to determine Hb level of children. The children dataset file was used for the analysis in this study. Children aged less than six months were excluded since their Hb levels were not measured. This study is based on 10,480 children aged 6-59 months identified during the survey. However, Hb levels of 10,221 (97.5%) children were measured. Other children were either not present or refused to participate. Also, valid height-for-age measurement were obtained for 10,213 (97.4%) children.

Dependent variable

The outcome variable was CAS in urban and rural areas. This was obtained by identifying 6-59 months aged children with height-for-age Z score below minus two standard deviation (-2SD) from the median of the reference population based on WHO Child Growth Standards and simultaneously having an Hb level of less than 110g/dL. The outcome variable was coded as "1" for CAS and "0" otherwise. Following Gosdin *et al.* (2018), expected frequency of co-occurrence was the product of the prevalence of anemia and stunting. The squared difference of the observed and expected frequencies of co-occurrence divided by the expected was the chi-squared statistic with one degree of freedom.

Explanatory variables

The explanatory variables represent socio-demographic characteristics of the child, mother and household and indicators of causes of stunting and anemia based on the conceptual framework. The explanatory variables include child and mother's age, child's gender, indicators of child health (incidence of diarrhea, fever, and cough two weeks before the survey), uptake of vitamin A dose, iron pills, and drugs for intestinal parasites, child vaccination status, dietary diversity score, maternal education, marital status, household wealth, region, source of drinking water and sanitation practice. The dietary diversity score is the number of food groups consumed by a child in the last 24 hours before the survey. The minimum acceptable number recognized internationally is four (WHO 2010). Age of the child and mother were included as categorical variables in the bivariate analysis and as continuous variables in the regression analysis.

Statistical analysis

Non-proportional allocation of samples to the states in the country during the 2018 NDHS survey necessitated the use of sampling weights in all the analyses. The Complex Samples option was used to identify weighting, clustering and stratification variables.

Descriptive statistical analyses were used for data description. Pearson Chi-square tests was used to determine the association between the dependent and independent variables in the bivariate model. Correlation analysis and Variance Inflation Factor were used to test for multicollinearity among the independent variables. Multivariate binary logistic regression was used to determine the predictors of CAS in rural and urban areas. Given the variation in social conditions in urban and rural areas, understanding the predictors of CAS in each residential area was necessary. Association between the dependent and explanatory variables in the logistic regression model was measured using the odds ratio. The F-statistic test was conducted to determine the goodness of fit of the regression model. The significance level was set at $p < 0.05$ for both bivariate and regression analyses. Statistical package for the Social Sciences 25.0 was used for the analyses.

The presence and degree of spatial autocorrelation (dependency) in the distribution of CAS across the 36 states in the country was analyzed using global Moran's I statistic (Anselin, 1988). Global Moran's *I* statistic test the null hypothesis that there is no spatial association, that is, the values in each location are independent. The value of Moran's *I* varies from -1 to 1. A positive value indicate that neighboring districts have similar values and the pattern is clustered. A negative value indicate that the districts have different values and the pattern is regular while zero indicates a random pattern. The null hypothesis is rejected if Moran's *I* is statistically significant at $p < 0.05$. Global Moran's *I* was computed as follows:

$$I = \frac{N \sum_i \sum_j W_{ij} (X_i - \bar{X})(X_j - \bar{X})}{(\sum_i \sum_j W_{ij}) \sum_i (X_i - \bar{X})^2} \qquad (1)$$

where N is the number of districts, i is a specific district, j is the neighboring district to i, w_{ij}

represent the row-standardized weight spatial matrix of observation at i and j, Xi is the value for feature i (sum up to N), Xj is the value for neighboring point j (up to N-1).

Anselin Local Moran's I statistic was used to detect local areas of similar or dissimilar values, that is, clusters and outliers. Clusters are classified into hotspots (districts with high values next to district with similarly high values-HH), and "coldspots" (district with low values next to district with similarly low values-LL). Spatial outliers are districts with dissimilar values next to each other, that is, high next to low-HL or low next to high-LH. The expected value of local Moran's I under the null hypothesis of no spatial dependence is -1/(N-1). Geographic coordinates of districts were obtained from the MEASURE DHS geographic data files. ArcGIS 10.0 software was employed.

Furthermore, the determinants of the spatial variation of CAS at district level across the 36 states and FCT was analyzed using the approach of geographically weighted Poisson regression (GWPR). Areal disease datasets with low counts are better analyzed using Poisson regression (Nakaya *et al.,* 2005). However, global models such as Poisson regression do not account for geographical variations in the factors that determine disease incidence rates. Geographically weighted Poisson regression examines geographical variation of regression parameters by deriving local estimates of regression parameters for each location in space (Chen *et al*., 2012). Both constant and geographically varying local parameters can be included in a GWPR model. The global Poisson regression (GPR) is defined as:

$$\text{In}\,(Y) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \ldots\ldots.\beta_j X_j \qquad (1)$$

where In (Y) is the natural log of expected count of children with CAS per state, β_0 is the intercept, $\beta_1 \ldots j$ are the parameters, and X_i X_j are the explanatory variables. When the parameter estimates vary with geographical location $u_i = u_{xi}\, v_{yi,}$ which is the two dimensional geographic coordinates of the centroid of the ith district in space, the GWPR model of equation 1 is stated as:

$$\text{In}(Y) = \beta_0\,(\mu_i) + \beta_1\,(\mu_i)\,X_1 + \beta_2\,(\mu_i)\,X_2 + \ldots\ldots.\beta_j\,(\mu_i)\,X_j \qquad (2)$$

The parameter β (β_0, β_1, $\beta_2 \ldots \beta_j$) estimated in Eq. (2) is different between states. Hence, the GWPR addresses the spatial heterogeneity problem. The coefficients $\beta j(u_{xi}\ v_{yi})$ are assumed to be smoothly varying conditional on their location. A spatial weighting kernel is used to estimate smoothed geographical variations of coefficients. The Gaussian and bi-square adaptive kernels are used to estimate the geographical weight assigned locally to observations. The weights decrease with increasing distance between the regression point i and the location of the observation. Observations closer to the regression point i are assigned higher weights than those farther away (Chen *et al*., 2012).

In this study, fixed Gaussian kernel function was used to determine the geographical weights while corrected Akaike Information Criterion (AICc) was employed to select the bandwidth size, weighting function and the best model. The GWPR analysis was conducted using the number of children with concurrent anemia and stunting as dependent variable while the explanatory variables are the socio-demographic characteristics of the child, mother and household that were applied in the binary logistic regression analysis. Several combinations of the explanatory variables were fitted into various GWPR models and the model with the best performance (based on the AICc) was selected. The final GWPR model comprised of only nine explanatory variables. The estimated local estimates for each of the explanatory variable was used to map the spatial distribution of regression parameters in the 36 states and FCT. The GWR 4.0.90 software was used to implement GWPR model.

Results

Characteristics of the children, mothers/caregivers and households are presented based on their place of residence in table 1. Among 10,480 children, 5857.3 (55.9%) lived in rural areas. The mean age of the children $\pm$ S.D. was 31.5 $\pm$ 15.63 months. In terms of gender, 51.2 % of the children were males (5362.9) while 48.8% (5117.9) were females. The mean age of the caregivers was 30.0 $\pm$ 6.70 years. Most of the children were anemic (68%) while less than half (38.8%) were stunted. Although CAS was observed in 2956 (29.2%) children, a higher (70.3%) proportion of these children live in rural areas.

Table 1: Characteristics of households, women and children by place of residence

		Urban 4623.6		Rural 5857.3		Total 10, 480.9	%	
Variable	Categories	*N*	%	*N*	%			*p*-value
Source of drinking water	Unimproved water	1122.8	30.8	2517.7	69.2	3640.5	35.2	0.000
	Improved water	3427.8	51.1	3276.1	48.9	6703.9	64.8	
Type of sanitation facility	Unimproved sanitation	1105.1	23.9	3509.1	76.1	4614.1	44.5	0.000
	Improved sanitation	3457.3	60.2	2289.3	39.8	5746.6	55.5	
Diet diversity score	<4	3942.1	42.5	5328.2	57.5	9270.3	88.4	
	>4	681.5	56.3	529.0	43.7	1210.6	11.6	0.000
Breastfeeding status	Breastfeeding Still	992.9	37.3	1665.6	62.7	2658.5	25.4	0.000
	Ever breastfed not currently breastfeeding	3561.2	46.6	4086.6	53.4	7647.7	73.0	
	Never breastfed	69.6	39.9	105.1	60.1	174.7	1.7	
Size at birth	Small	490.6	39.1	764.5	60.9	1255.0	12.1	0.037
	Average	2470.8	44.4	3099.4	55.6	5570.2	53.8	
	Large	1600.7	45.5	1920.5	54.5	3521.2	34.0	
Vaccination	No	237.5	27.1	637.5	72.1	874.9	25.7	0.000
	Yes	1066.4	42.2	1459.9	57.8	2556.3	74.3	
Intake of Vitamin A	No	929.9	33.6	1834.2	66.4	2764.1	46.4	0.000
	Yes	1734.1	54.3	1457.1	45.7	3191.2	53.6	
Episode of diarrhea	No	4147.3	45.6	4951.2	54.4	9098.5	86.8	0.000
	Yes	475.8	34.5	903.8	65.5	1379.6	13.2	
Fever	No	3666.9	47.5	4060.5	52.5	7727.4	73.7	0.000
	Yes	956.3	34.8	1794.6	65.2	2750.8	26.3	
Cough	No	3873.3	44.2	4894.2	55.8	8767.5	83.7	0.846
	Yes	749.9	43.8	961.5	56.2	1711.4	16.3	
Iron Pills	No	3458.8	41.0	4984.6	59.0	8443.4	80.8	0.000
	Yes	1153.9	57.6	847.9	42.4	2001.8	19.2	
Drug for intestinal parasite	No	2863.9	38.5	4571.9	61.5	7435.8	71.3	0.000
	Yes	1739.3	58.1	1253.6	41.9	2992.8	28.7	
Child's age	6-11	535.2	42.0	740.6	58.0	1275.8	12.2	0.234
	12-23	1123.5	45.1	1365.2	54.9	2488.4	23.7	
	24-35	1012.9	45.6	1206.1	54.4	2218.9	21.2	
	36-47	1000.7	44.0	1275.7	56.0	2276.5	21.7	
	48-59	951.7	42.8	1269.6	57.2	2221.3	21.2	
Caregiver's anemia Status	No	2088.8	49.1	2162.8	50.9	4251.6	41.7	0.000
	Yes	2413.8	40.6	3532.4	59.4	5946.2	58.3	
Caregiver's age	15-19	74.0	22.0	262.9	78.0	336.9	3.2	0.000
	20-30	2363.1	41.5	3330.3	58.5	5693.4	54.3	
	31-40	1893.0	50.1	1884.3	49.9	3777.3	36.0	
	41-49	293.5	43.6	379.7	56.4	673.2	6.4	
Region	North Central	473.4	32.6	977.7	67.4	1451.1	0.6	0.000
	North East	457.8	28.0	1176.7	72.0	1634.5	15.6	
	North West	791.9	26.0	2257.7	74.0	3049.6	29.1	
	South east	994.1	72.7	374.2	27.3	1368.4	13.1	
	South South	458.9	41.0	659.5	59.0	1118.4	10.7	
	South West	1447.5	77.9	411.4	221.1	1858.9	17.7	
Educational level	No	791.8	19.4	3295.4	80.6	4087.3	39.0	
	Primary	725.3	43.0	963.1	57.0	1688.3	16.1	0.000
	Secondary	2292.5	62.2	1395.7	37.8	3688.2	35.2	
	Higher	813.9	80.0	203.1	20.0	1017.1	9.7	
Sex of household head	Male	4029.7	43.1	5327.5	56.9	9357.2	89.3	0.000
	Female	593.9	52.9	529.77	47.1	1123.7	10.7	
Wealth quintile	Poorest	169.2	8.7	1784.9	91.3	1954.1	18.6	

	Poorer	340.9	16.8	1686.1	83.2	2027.0	19.3	0.000
	Middle	880.4	40.1	1316.9	59.9	2197.3	21.0	
	Richer	1511.4	68.3	700.3	31.7	2211.7	21.1	
	Richest	1721.7	82.3	369.1	17.7	2090.7	19.9	
Health Insurance	No	4418.1	43.3	5791.9	56.7	10210	97.4	0.000
Yes	Yes	205.6	75.9	65.3	24.0	270.9	2.6	
Marital status	Never in Union	77.4	42.9	102.9	57.1	180.4	1.7	0.060
	Currently in union /living with a man	4394.9	43.9	5618.8	56.1	10013.6	95.5	
	Former in union	151.3	52.8	135.5	47.2	286.9	2.7	
Child's sex	Male	2432.8	45.4	2930.2	54.6	5362.9	51.2	0.036
	Female	2190.8	42.8	2927.1	57.2	5117.9	48.8	
Type of Mosquito bed net	No net	2538.9	52.7	2276.9	47.3	4815.9	48.7	0.000
	Only treated net	2043.4	36.6	3544.5	63.4	5587.9	50.5	
	Only untreated net	41.3	54.0	35.1	46.0	76.3	0.7	
Anemic	No	1696	52.0	1563.5	48.0	3260.2	31.9	0.000
	Yes	2797.6	40.2	4164.0	59.8	6961.6	68.1	0.000
Stunted	No	3255.2	52.1	2994.5	47.9	6249.7	61.2	
	Yes	1268.8	32.0	2694.5	68.0	3963.3	38.8	0.000
Anemic and stunted concurrently	No	3597.7	50.1	3583.3	49.9	7181.0	70.8	
	Yes	879.0	29.7	2077.1	70.3	2956.1	29.2	0.000

p-value at 5% significance level

There was a statistically significant difference between urban and rural areas with regards to source of drinking water, type of sanitation facilities, diet diversity score, breastfeeding status, uptake of vaccines, vitamin A pills, iron pills, and drug for intestinal parasites, child's sex, occurrence of diarrhea and fever, caregivers anemia status, age, educational level, household wealth quintile, number of under-five children, region, proportion of children that were anemic, stunted and those that experienced both conditions.

Results of the bivariate analysis of the association between socio-demographic and health variables and CAS (table 2) indicate that CAS was significantly associated with type of sanitation facilities, diet diversity score, size at birth, uptake of vitamin A capsules and drug for intestinal parasites, episode of diarrhea and fever, child's age, caregiver's anemia and educational status, number of under-five children, region of residence, household wealth quintile, availability of health insurance, and type of mosquito net used by children in both urban and rural areas. In addition, vaccination status of the child and mother's age were significantly associated with CAS in urban areas only. In rural areas, statistically significant relationship existed between CAS and source of drinking water, consumption of iron pills, sex of household head, marital status, and work status of the caregiver. These variables were not statistically significant in urban areas.

The prevalence of CAS was higher (41.1%) among children in rural households that do not have access to improved source of drinking water. Children in households that lack improved sanitation facilities had higher prevalence of CAS in urban (82.6%) and rural (40.3%) areas. In both urban and rural areas, prevalence of CAS was higher among children with a diet diversity score of less than four, small size at birth, did not receive childhood vaccines, iron pills and drugs for intestinal parasites and those that experienced diarrhea and fever two weeks before the survey. Whereas the prevalence of CAS was highest (24.9%) among children aged 12-23 months in urban areas, 24-35 months aged children had the highest (44.0%) prevalence in rural areas. In both urban (22.0%) and rural (39.3%) areas, prevalence of CAS was higher among children whose caregiver was anemic. Caregiver's age was significantly related to CAS in urban areas only. Prevalence was higher among children whose caregiver was aged 15-19 years (20.5%) and 41-49 years (20.6%). By geographical region, North West zone had the highest prevalence of CAS in both urban (32.3%) and rural (50.7%) areas. Children in urban (37.2%) and rural (47.3%) areas whose caregivers had no formal education had the highest prevalence levels. Prevalence of CAS was highest among children living in poorest households in both urban (44.7%) and rural (49.8%) areas. Children in households that did not have health insurance had higher prevalence of CAS in rural (36.9%) and urban (20.1%) areas. With regards to marital status, in both urban (19.7%) and rural (37.2%) areas, prevalence of co-occurrence was higher in children whose caregiver was in union during the survey. Generally, male children had higher prevalence of CAS compared to female children.

Table 2: Co-occurrence of stunting and anemia by characteristics of study participants in rural and urban areas

	Urban				**Rural**			
Variable and Categories	No	Yes	Total	p-value	No	Yes	Total	p-value
Not improved water	862.0(78.7)	232.8(21.3)	1094	0.39	1415.3(58.9)	988.2(41.1)	2403.5	0.00
Improved water	2674.9(80.8)	637.4(19.2)	3312.4		2125.1(66.50	1069.4(33.50	3194.5	
Not improved sanitation	779.5(73.0)	2765.7(82.6)	1057.0	0.00	2020.4(59.7)	1366.7(40.3)	3387.1	0.00
Improved sanitation	2765.7(82.6)	582.7(17.4)	3348.4		1520.2(68.6)	695.2(31.4)	2215.4	
Diet diversity: <4	3031.9(79.5)	782.5(20.5)	3814.4	0.01	3227.7(62.7)	1919.2(37.3)	5146.8	
>4	565.8(85.4)	96.5(14.6)	662.3		355.7(69.20	157.9(30.8)	513.6	0.01
Breastfeeding: Still breastfeeding	740.1(77.7)	212.8(22.3)	952.9	0.15	1025.7(64.0)	577.5(36.0)	1603.3	0.80
Ever breastfed not currently breastfeeding	2797.5(81.0)	657.8(19.0)	3455.4		2491.4(63.0)	1463.0(37.0)	3954.5	
Never breastfed	60.1(87.8)	8.3(12.2)	68.4		66.2(64.4)	36.5(35.6)	102.7	
Size at birth: small	354.9(74.4)	122.0(25.6)	476.8	0.05	404.1(55.0)	330.1(45.0)	734.2	0.00
Average	1943.2(81.1)	451.7(18.9)	2394.9		1976.1(65.7)	1031.1(34.3)	3007.2	
Large	1254.8(81.2)	290.7(18.8)	1545.5		1160.1(62.6)	692.6(34.4)	1852.7	
Vaccination: No	147.9(64.5)	81.3(35.5)	229.1	0.00	353.5(58.9)	247.0(41 .1)	600.5	0.75
Yes	789.8(76.6)	241.9(23.4)	1031.7		814.7(57.9)	593.5(42.1)	1408.2	
Vitamin A intake: No	650.2 (71.9)	253.7(28.1)	903.9	0.00	1044.7(59.1)	722.8(40.9)	1767.5	0.00
Yes	1364.7(81.0)	320.1(19.0)	1684.8		956.2(67.7)	455.6(32.3)	1411.8	
Diarrhea: No	3287.0(81.9)	728.7(18.1)	4015.7	0.00	3131.9(65.5)	1650.7(34.5)	4782.6	0.00
Yes	310.7(67.4)	150.4(32.6)	461.0		451.4(51.6)	424.1(48.4)	875.5	
Fever: No	2878.3(81.2)	664.3(18.8)	3542.5	0.01	2605.9(66.7)	1303.6(33.3)	3909.5	0.00
Yes	719.4(77.0)	214.8(23.0)	934.2		977.4(55.9)	771.4(44.1)	1748.8	
Cough: No	3004.9 (80.1)	746.9(19.9)	3751.8	0.34	3022.8(63.9)	1709.9(36.1)	4732.7	0.07
Yes	592.8(81.8)	132.1(18.2)	724.9		560.5(60.5)	365.7(39.5)	926.2	
Iron Pills No	2679.8(79.8)	680.1(20.2)	3359.9	0.22	2985.8(61.9)	1835.3(38.1)	4821.1	0.00
Yes	907.4(82.0)	198.9(18.0)	1106.4		585.9(71.8)	229.7(28.2)	815.6	
Drug for intestinal parasite: No	2132.7(76.6)	652.0(23.4)	2784.7	0.00	2650.7(60.1)	1762.2(39.9)	4412.9	0.00
Yes	1446.6(86.5)	224.9(13.5)	1671.5		914.4(75.2)	302.2(24.8)	1216.6	
Child's age: 6-11	448.7(86.8)	68.5(13.2)	517.2	0.00	542.5(76.9)	162.8(23.1)	705.3	0.00
12-23	817.5(75.1)	270.9(24.9)	1088.4		820.8(61.7)	508.9(38.3)	1329.8	
24-35	755.9(76.3)	234.4(23.7)	990.3		652.7(56.0)	512.1(44.0)	1164.8	

36-47	792.1(81.2)	183.5(18.8)	975.6		729.6(59.4)	499.7(40.6)	1229.3	
48-59	783.5(86.6)	121.7(13.4)	905.2		837.7(68.0)	393.5(32.0)	1231.3	
Mother's anemia status: No	1721.7(83.4)	343.8(16.6)	2065.6	0.00	1441.6(67.8)	686.1(32.2)	2127.7	0.00
Yes	1852.6(78.0)	523.5(22.0)	2376.1		2088.5(60.7)	1349.7(39.3)	3438.2	
Mother's age: 15-19	53.2(79.5)	13.7(20.5)	66.9	0.03	153.2(61.1)	97.6(38.9)	250.8	0.38
20-30	1778.2(78.3)	491.5(21.7)	2269.8		2001.0(62.6)	1198.0(37.4)	3199.1	
31-40	1539.5(83.0)	314.9(17.0)	1854.5		1196.8(65.2)	638.6934.8)	1835.5	
41-49	226.7(79.4)	58.8(20.6)	285.5		232.3(61.9)	142.9(38.1)	375.1	
Region : North Central	387.7 (83.5)	76.7(16.5)	464.5	0.00	741.6(76.7)	225.4(23.3)	967.1	0.00
North East	304.1(69.7)	132.1(30.3)	436.1		642.5(56.7)	490.0(43.3)	1132.5	
North West	520.4(67.7)	248.1(32.3)	768.5		1062.6(49.30	1093.5(50.7)	2156.1	
South East	829.2(85.9)	136.1(14.1)	965.3		304.1(83.8)	58.9(16.2)	363.1	
South South	384.9(86.5)	59.9(13.5)	444.8		510.2(79.7)	129.9(20.3)	640.1	
South West	1171.3(83.8)	226.1(16.2)	1397.4		322.2(80.2)	79.3(19.8)	401.5	
Education: No	477.4(62.8)	282.3(37.2)	759.8	0.00	1668.2(52.7)	1495.7(47.3)	3163.9	
Primary	499.8(72.0)	194.3(28.0)	694.0		641.4(68.3)	297.7(31.7)	939.1	0.00
Secondary	1895.7(84.7)	343.1(15.3)	2238.8		1097.5(80.7)	261.8(19.3)	1359.3	
Higher	724.7(92.4)	59.3(7.6)	784.1		176.2(88.9)	19.3(21.9)	1359.3	
Sex of household head: Male	3131.1(80.3)	769.9(19.7)	3900.9	0.72	3213.6(62.5)	1930.4(37.5)	5143.9	0.00
Female	466.6(81.0)	109.1(19.0)	575.7		39.8(71.6)	146.7(28.4)	516.5	
Wealth : Poorest	90.4(55.3)	73.2(44.7)	163.6	0.00	856.1(50.2)	847.7(49.8)	1703.8	
Poorer	204.6(62.0)	125.5(38.0)	330.1		933.5(56.9)	705.9(43.1)	1639.5	0.00
Middle	644.7(74.7)	218.5(25.3)	863.3		920.1(72.4)	351.6(27.6)	1271.6	
Richer	1147.9(78.6)	312.5(21.4)	1460.5		555.7(81.1)	129.9(18.9)	685.6	
Richest	1509.9(91.0)	149.3(9.0)	1659.3		317.9(88.3)	41.9(11.7)	359.9	
Health Insurance: No	3416.9(79.9)	860.0(20.1)	4276.9	0.00	3535.9(63.1)	2064.4(36.9)	5600.3	0.00
Yes	180.8(90.5)	19.0(9.5)	199.8		47.4(78.8)	12.7(21.2)	60.1	
Marital status: Never in Union	60.6(81.3)	13.9(18.7)	74.6	0.95	80.1(83.8)	15.5(16.2)	95.6	0.00
Currently in union /living with a man	3415.2(80.3)	836.8(19.7)	4252.1		3409.9(62.8)	2020.8(37.2)	5430.9	
Former in union	121.8(81.2)	28.2(18.8)	150.0		93.4(69.6)	40.8(30.4)	134.2	
Child 's sex: Male	1844.1(78.3)	512.3(21.7)	2356.4	0.00	1683.5(59.5)	1144.1(40.5)	2827.7	0.00
Female	1753.6(82.7)	366.7(17.3)	2120.3		1899.8(67.1)	932.9(32.9)	2832.8	
Type of Mosquito bed net: No net	2065.4(83.3)	414.0(16.70	2479.4	0.00	1647.0(67.0)	809.8(33.0)	2456.8	0.00
Only treated net	1500..7(76.5)	460.9(23.5)	1961.6		1912.8(60.4)	1255.3(39.6)	3168.1	
Only untreated net	31.6(88.6)	4.1(11.4)	35.7		23.1(65.8)	12.0(34.2)	35.1	

Observed and expected prevalence of co-occurrence of anemia and stunting

As shown in table 3, the observed prevalence of co-occurrence of anemia and stunting in urban and rural areas was 19.6% and 36.7% while the expected prevalence by chance was 17.4% and 34.5% respectively. There was no statistically significant difference between the observed and expected frequency of co-occurrence of anemia and stunting in urban and rural areas as well as among all the study participants.

Table 3: Comparison of observed and expected prevalence of co-occurrence of anemia and stunting

	Urban	Rural	All
Anemic	62.2	72.7	68.1
Stunted	28.0	47.4	38.8
Observed co-occurrence	19.6	36.7	29.2
Expected co-occurrence	17.4	34.5	26.4
X^2	0.28	0.14	0.30
p-value	0.60	0.71	0.58

Predictors of co-occurrence of anemia and stunting

Table 4 presents results of the multivariable logistic regression analysis of the predictors of anemia and stunting co-occurrence. The F-test showed that goodness of fit of the model for urban (F=3.772, p= 0.000) and rural (F=16.610, p= 0.000) areas, as well as the pooled data (F=19.534, p= 0.000) were good. Although not statistically significant, children with small size at birth consistently had higher odds of being anemic and stunted concurrently. In the pooled data, the odds of anemia and stunting co-occurring among children with average size at birth was significantly lower compared to those that were large at birth (adjusted odds ratio-aOR: 0.78, 95% CI; 0.62-0.96). Episode of diarrhea in children was significantly associated with co-occurrence of anemia and stunting in the pooled data, urban and rural areas. Children who did not report diarrhea two weeks before the survey were consistently less likely to be anemic and stunted simultaneously compared to those that had diarrhea (aOR: 0.60-0.72, p< 0.05). There was a significant association between child's age and CAS in the rural areas and pooled sample (aOR: 1.06-1.09, p< 0.000). Compared with female children, male children in rural areas (aOR: 1.43, 95% CI; 1.16-1.76) and the pooled sample (aOR: 1.40: 95% CI; 1.17-1.67) were 43% and 40% more likely to be anemic and stunted concurrently.

Breastfeeding status of children was significantly associated with CAS in children. Children in urban areas who were still breastfeeding (aOR: 5.90: 95% CI; 1.35-25.70) and those that were breastfed previously (aOR: 6.91, 95% CI; 1.71-27.95) were six times and seven times more likely to be anemic and stunted concurrently compared to those who were never breastfed. In the pooled data, children that were still breastfeeding were nearly three times more likely to be anemic and stunted simultaneously compared to those that were never breastfed. Compared to urban children whose mothers were anemic, those whose mothers were not anemic had significantly lower odds of being anemic and stunted simultaneously (aOR: 0.67, 95% CI; 0.49-0.96). Level of education of the mother/caregiver had statistically significant trends in odds ratios of CAS in children (p< 0.05). This means that as level of education increased, the odds ratio of CAS decreased. In urban areas, children whose caregivers had no formal and primary education were four times and two times more likely to experience CAS respectively compared to those with higher educational level (aOR: 2.51-4.05, p< 0.05). However, in the pooled data, children whose caregivers had no formal and primary education were nearly three times and two times more likely to be anemic and stunted concurrently compared to those with higher education (aOR:2.17-2.92, p< 0.05).

Table 4: Predictors of co-occurrence of anemia and stunting

		Urban		Rural		All	
Variable	Categories	ExpB	CI	ExpB	CI	ExpB	CI
Size at birth	Small	1.23	1.69-2.16	1.42	0.97-2.07	1.344	0.99-1.83
	Average	0.64	0.40-1.03	0.85	0.67-1.08	0.770*	0.62-.96
	Large	1.0	Ref.	1.0	Ref.	1.0	Ref.
Vaccination	No	1.06	0.66-1.69	0.86	0.65-1.14	0.94	0.74-1.19
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Vitamin A	No	1.01	0.67-1.52	1.06	0.81-1.39	0.98	0.79-1.23
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Had diarrhea 2 weeks before survey	No	0.59*	0.36-0.99	0.72*	0.53-0.99	0.67**	0.52-0.88
	Yes	1.0	Ref.	1.000		1.000	
Had fever 2 weeks before survey	No	1.05	0.65-1.69	0.79	0.60-1.03	0.87	0.69-1.09
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Had cough 2 weeks before survey	No	1.19	1.71-1.99	0.85	0.64-1.13	0.98	0.77-1.25
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Iron Pills No	No	0.75	0.46-1.24	1.03	0.73-1.46	0.89	0.664-1.22
	Yes	1.0		1.0		1.0	
Drug for intestinal parasite	No	1.23	0.76-1.99	0.88	0.595-1.310	1.07	0.785-1.46
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Child's age	Child's age	1.03	0.99-1.06	1.09***	1.06-1.11	1.06***	1.04-1.08
Breastfeeding status	Still Breastfeeding	5.89*	1.353-25.679	2.218	0.825-5.964	2.761**	1.292-4.253
	Ever breastfed	6.92**	1.71-27.95	1.14	0.43-3.03	2.01	1.95-4.25
	Never breastfed	1.0	Ref.	1.0	Ref.	1.0	Ref.
Sex of child	Male	1.38	0.97-1.96	1.43**	1.16-1.76	1.39***	1.17-1.67
	Female	1.0	Ref.	1.0	Ref.	1.000	Ref.
Diet diversity score	Less than 4	0.88	0.50-1.52	1.15	0.79-1.68	0.89	0.72-1.37
	4 and above	1.00	Ref.	1.000	Ref.	1.0	Ref.
Type of mosquito bed net	No net	385.4	385.4-385.4	1.72	0.23-12.68	3.15	0.54-18.39
	Only treated net	460.8	460.8-460.8	1.793	0.244-13.169	3.495	0.595-20.520
	Both treated and untreated	-	-	3.17E-9***	1.936E-10-5.211E-8	5.060E-9***	3.580E-10-7.15E-8
	Only untreated net	1.0	Ref.	1.0	Ref.	1.0	Ref.
Mother's anemia	No	0.69*	0.49-0.96	0.93	0.74-1.18	0.84	0.69-1.02
	Yes	1.0	Ref.	1.0	Ref.	1.0	Ref.
Caregiver's age	Mother/Caregiver's age	0.99	0.96-1.02	0.99	0.98-1.02		

Education	No	4.05**	1.75-9.38	2.14	0.78-5.85	2.92***	1.60-5.33
	Primary	2.51*	1.08-5.82	1.74	0.64-4.78	2.17**	1.18-4.00
	Secondary	1.71	0.86-3.38	1.34	0.51-3.56	1.64	0.96-2.81
	Higher	1.0	Ref.	1.0	Ref.	1.0	Ref.
Marital status	Never in Union	0.57	0.09-3.63	0.70	0.20-2.45	0.65	0.23-1.81
	Currently in union /living with a man	0.88	0.31-2.51	0.95	0.45-2.01	0.92	0.52-1.66
	Former in union	1.0	Ref.	1.0	Ref.	1.0	Ref.
Source of drinking water	Unimproved	1.56*	1.03-2.38	1.03	0.79-1.34	1.16	0.92-1.45
	Improved	1.00	Ref.	1.0	Ref.	1.0	Ref.
Sanitation facility	Unimproved	0.62	0.38-1.03	0.88	0.65-1.18	0.77*	0.597-0.99
	Improved	1.00	Ref.	1.0	Ref.	1.0	Ref.
Region	North Central	1.07	0.58-1.95	0.82	0.46-1.48	0.88	0.56-1.36
	North East	1.34	0.65-2.79	1.49	0.82-2.68	1.41	0.90-2.20
	North West	1.70	0.93-3.09	2.06*	1.18-3.61	1.91**	1.26-2.88
	South East	0.65	0.37-1.19	0.85	0.40-1.79	0.69	0.43-1.13
	South South	1.47	0.62-3.51	1.09	0.55-2.15	1.237	0.72-2.14
	South West	1.0	Ref.	1.0	Ref.	1.0	Ref.
Sex of household head	Male	0.86	0.51-1.45	1.24	0.79-1.95	1.06	0.75-1.49
	Female	1.0	Ref.	1.0	Ref.	1.0	Ref.
Wealth quintile	Poorest	3.47**	1.43-8.41	2.13*	1.01-4.52	2.84***	1.67-4.82
	Poorer	3.27**	1.59-6.68	2.13*	1.05-4.31	2.78***	1.72-4.49
	Middle	1.58	0.91-2.75	1.19	0.60-2.35	1.56*	1.01-2.41
	Richer	1.56	0.89-2.75	1.18	0.57-2.47	1.54	0.97-2.46
	Richest	1.0	Ref.	1.0	Ref.	1.0	Ref.
Health Insurance	No	0.64	0.23-1.81	5.44*	0.96-30.79	1.31	0.50-3.41
Place of residence	Urban					1.09	0.84-1.41
	Rural					1.0	Ref.
F		3.772	0.000	16.610	0.000	19.53	0.00

*: p <0.05, **: p <0.01, ***: p <0.001

In the pooled sample, rural and urban areas, children in households that obtain drinking water from unimproved sources were more likely to experience CAS compared to those that obtain water from improved sources. However, the odds of this variable was only statistically significant in urban areas (aOR: 1.56, 95% CI; 1.03-2.38). The pooled data indicate that children in households that use unimproved sanitation facilities had lower odds of experiencing anemia and stunting concurrently compared to those in households that utilize improved sanitation facilities (aOR: 0.77, 95% CI; 0.60- 0.99). The likelihood of children in North West zone reporting anemia and stunting concurrently compared to those in the South West zone was significantly higher in rural areas and the pooled sample (aOR: 1.91-2.06, p< 0.05). The association between household wealth and CAS was consistently significant in the pooled data, urban and rural areas. Compared with children in richest households, those in poorest and poorer households in urban areas (aOR: 3.27-3.47, p< 0.05), rural areas (aOR: 2.12-2.13, p< 0.05), and the pooled data (aOR: 2.78-2.84, p< 0.05) had higher odds of being anemic and stunted concurrently. Health insurance was positively associated with CAS. Children in households without access to health insurance were five times more likely to be anemic and stunted simultaneously compared to those in households with health insurance (aOR:

5.44, 95% CI; 0.96—30.79). Type of mosquito net used by children was significantly associated with co-occurrence of anemia and stunting in the pooled data and rural areas. Compared with children that slept under only untreated net, those that slept under both treated and untreated nets had higher odds of experiencing anemia and stunting concurrently (aOR: 3.17E-9-5.06E-9, $p < 0.001$).

Spatial pattern of co-occurrence of anemia and stunting

Of the 10,213 children aged 6-59 months, 3,963.3 (38.8%) were stunted. In addition, 68.1% (6,961.6) of the 10,221.8 children whose Hb level were measured were found to be anemic. Co-occurrence of anemia and stunting occurred in 2,956.1 (29.2%) out of 10,137.1 children that were measured for both conditions.

Rural-urban variation in the prevalence of CAS was observed. Whereas prevalence rate was 36.7% in rural areas, it was lower (19.6%) in urban areas. At state level, with the exception of Ekiti, Ebonyi, Osun, Kwara, Abia and Delta states, prevalence rate was higher in rural than urban areas in all other states. In rural areas, prevalence of CAS varied from 9.8% in Ekiti state to 60.5% in Kebbi state. Over 50% of children in rural areas of Bauchi, Gombe, Zamfara, Sokoto, Kano, Jigawa and Kebbi states had co-occurrence of anemia and stunting.

Prevalence of CAS was highest (55.8%) in urban areas of Jigawa state and lowest in Benue (2.5%) state. Other states with high prevalence rates in urban areas include Gombe (32.5%), Bauchi (33.9%), Yobe (34.0%), Borno (35.8%), Kano (40.7%), and Kebbi (44.0%) state. Generally, prevalence rate was higher (>27.0%) in rural areas of North Western states and lower in South Eastern and South Western states. Further, urban areas with high (>27.0%) prevalence rates were in states located in the North West (Jigawa, Kebbi, Kano, and Sokoto) and North East (Bauchi, Gombe and Bornu) zones. States with high (>27.0%) prevalence rates in their rural areas were mainly in the North West (Kebbi, Jigawa, Kaduna, Kano, Katsina, Sokoto and Zamfara states), South West (Oyo state), North Central (FCT-Abuja and Plateau state) and North East (Adamawa, Taraba, Yobe, Gombe and Bauchi states) zones.

Figure 1 shows the spatial distribution of children with CAS. Generally, prevalence of CAS varied from 9.9% in Lagos to 58.6% in Jigawa state. With regards to the distribution by geopolitical zones, CAS prevalence ranged from 13.5% in Benue state to 30.4% in Plateau state in the North Central zone. In North East zone, Bauchi state had the highest (48.5%) prevalence rate. This was followed by Gombe (46.6%) and Yobe state (42.5%) while Adamawa state had the lowest (27.6%) prevalence rate in the zone. With the exception of Kaduna state which had a prevalence rate of 29.6%, other states in the North West zone had high prevalence rates. Co-occurrence of anemia and stunting was observed in 58.6% of the children in Jigawa state, Kano (50.3%), Katsina (43.0%), Kebbi (58.4%), Sokoto (49.3%) and Zamfara (44.6%).

Prevalence of CAS was less than 21% in all the states located in the South East zone. Ebonyi state had the highest (20.4%) prevalence rate while Anambra state had the lowest (11.4%) rate. Similarly, in South South zone, prevalence rate varied from 14.8% in Edo state to 21.6% in Bayelsa state. In the South West zone, Oyo state had the highest (27.8%) prevalence rate while Lagos had the lowest (9.9%) rate. The results indicate that there is spatial variation in the distribution of prevalence of CAS across the states in the country with states in the North having a higher burden of the condition particularly states in the North West zone. Only 22 states had prevalence rates less than the national average of 27.0%.

The global Moran's I analysis results (table 5) reveal the presence of positive spatial autocorrelation in the data on CAS in the country. The Moran's I value (table 5) was statistically significant (I=0.666803, $p < 0.0000$) indicating a clustered pattern as neighboring districts had similar prevalence of CAS. Hence, the null hypothesis of spatial randomness is rejected. Results of the Anselin Local Moran's I analysis (figure 2) indicate that clustering of districts with high prevalence of CAS next to high ones (HH) were located in the North Western states of Sokoto, Zamfara, Katsina, Kano, Jigawa as well as Bauchi state in North East zone. Districts with low prevalence rate next to districts with low rates (LL) were mainly in the South West (Ekiti and Ondo states), South East (Enugu, Anambra, Imo, Abia, and Ebonyi states), South South (Delta, Cross

River, Bayelsa, Rivers Akwa Ibom and Edo states), and North Central (Kogi state) zone.

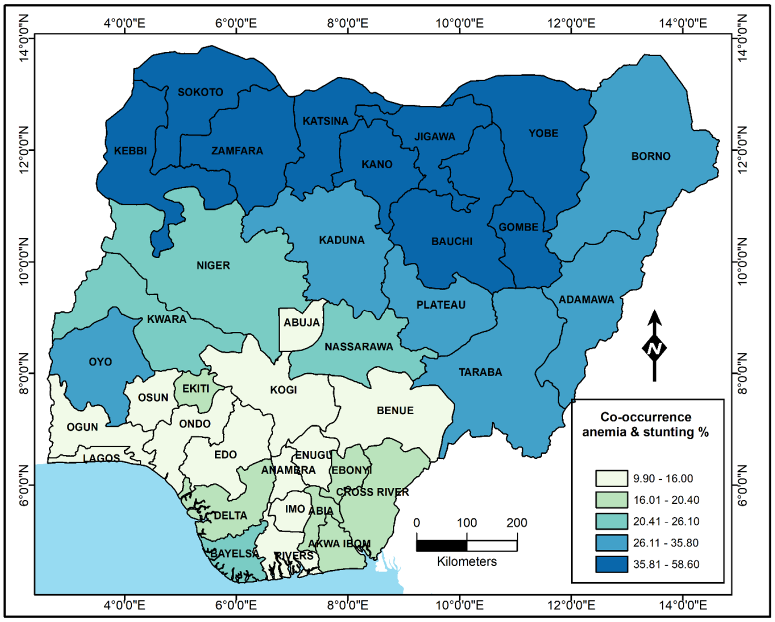

Figure 1: Distribution of children with co-occurrence of anemia and stunting in Nigeria

Table 5: Results of Global Moran's I analysis of co-occurrence of anemia and stunting

Variable	Global Moran's I index	Expected Index	Variance	Z score	*p*- value	Pattern
Co-occurrence of anemia and stunting	0.666803	-0.030303	0.011058	6.629102	0.00000	Clustered

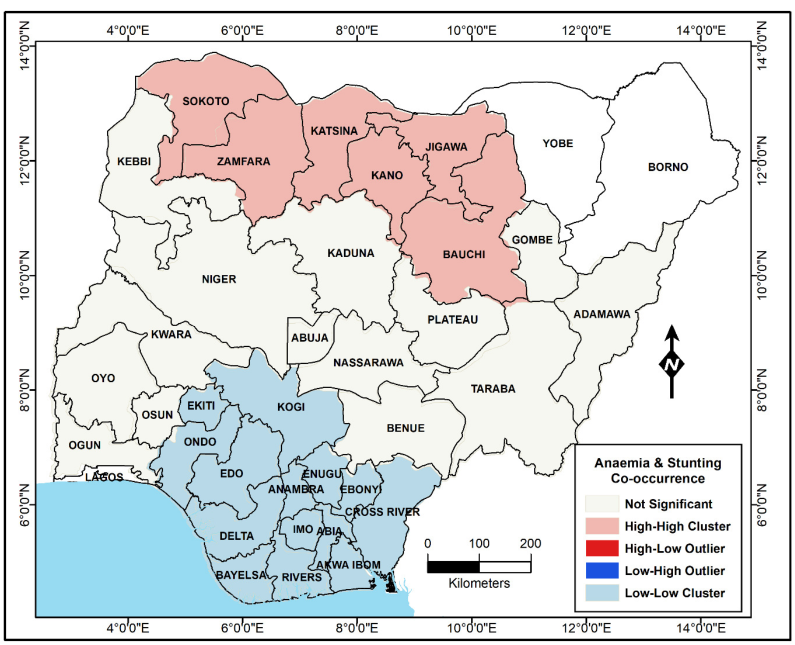

Figure 2: Cluster map of co-occurrence of anemia and stunting

Table 6 presents results of the GPR and GWPR. All the estimates of the explanatory variables are statistically significant in the global model. The AICc and deviance of the GPR (83.674, 55.203) is high compared with the values from the GWPR model (82.067, 45.497). In addition, the percentage of deviance explained by the GWPR model was 97.7%. This indicates that the performance of the GWPR model is better than the GPR model. The optimal bandwidth size of the GWPR model was 5.238.

Results of the GPR model shows that all the explanatory variables are statistically significant. However, the interquartile ranges of all the local parameter estimates are more than twice the standard errors of the global estimates suggesting that the variables varied across the study area, and the relationship between CAS and all the explanatory variables are not stationary but vary over space. Hence, a non-stationary model (GWPR) is appropriate for fitting the model.

Table 6: Summary of GPR and GWPR model results

	Global Poisson regression				Geographically Weighted Poisson regression			
Variable	Estimate	Standard Error	Z score	P- value	Mean	Standard Deviation	Interquartile range	Status
Intercept	2.903	0.067	43.240	<0.000	2.875	0.018	0.033	Non-stationary
Not improved water	0.016	0.002	7.605	<0.000	0.017	0.000	0.002	Non-stationary
Not improved sanitation	-0.005	0.001	-3.411	0.000	-0.004	0.000	0.001	Non-stationary
Child still breastfeeding	0.041	0.005	8.383	<0.000	0.040	0.004	0.006	Non-stationary
Not vaccinated	0.008	0.002	3.846	0.000	0.007	0.001	0.002	Non-stationary
Iron pills not taken	-0.006	0.002	-3.621	0.000	-0.006	0.000	0.001	Non-stationary
Drugs for intestinal parasites not taken	-0.006	0.002	-2.741	0.003	-0.007	0.000	0.001	Non-stationary
Anemic caregiver	0.023	0.003	8.697	<0.000	-0.023	0.000	0.001	Non-stationary
No formal education	-0.010	0.002	-6.499	<0.000	-0.011	0.000	0.006	Non-stationary
Small size at birth	0.007	0.002	4.014	0.000	0.008	0.001	0.020	Non-stationary
AICc	83.674				82.067			
R square	97.2				97.7			
Deviance	55.203				45.497			

Maps showing the spatial distribution of the local parameter estimate and t-value of each explanatory variable are presented in figure 3. Following Mennis (2006), standard deviation classification approach was used to classify the parameter estimates. Maps of the t-values highlight states where the t-values are significant, that is, exceed +/-1.96 (Chen *et al.,* 2012). Figure 3 shows that the distribution of the parameter estimate varies across the states. The parameter estimates of the variables not improved water, still breastfeeding, not vaccinated, anemic caregiver, and child's small size are positively associated with the variation of CAS. Variables which are negatively correlated with the prevalence of CAS are not improved sanitation, iron pills not taken, drugs for intestinal parasites not taken and no formal education.

The local parameter estimates of not improved water is high in the South South and South West zones as well as some states in the South East zone. The t-values of the local parameter estimate of the variable is significant in all the states. The parameter estimate of not improved sanitation is negative in all the states. However, the t-values associated with the parameter estimate are not significant in all the states.

The association between the parameter estimate of still breastfeeding and prevalence of CAS was positive and high in states located in the North East zone and some states in the North West zone. In all the states, the t-value indicates that the parameter estimates are significant in all the states. States in the North East zone have high value of the parameter estimate not vaccinated while low values were exhibited in the South West and South South zones. The association between prevalence of CAS and not vaccinated is significant in all the states.

The relationship between the local parameter estimate of iron pills not taken and CAS is negative across the states but it is high in the South South, South West and South East states. However, the variable is not significant in all the states. The local parameter estimate of drug for intestinal parasite not taken is negative in all the states and high in the North East and North West zones. However, the t-values are not significant in all the states. States in the south have high values of the local parameter estimate of anemic caregivers compared to the states in the north. Furthermore, the parameter estimate is significant in all the states.

The local parameter estimates of no formal education was negative and high in the South West zone, as well as Kebbi and Sokoto states in the North West zone. The association between CAS and no formal education is however not significant in all the states. States in the South West, South South, and South East zones have high local parameter estimates of the variable child's small size at birth while states in the North East zone have the lowest estimate. The t-values of the parameter estimates was significant in all the states.

Generally, the spatial variability maps of the GWPR parameter estimates showed that the significant variables are not improved water, child still breastfeeding, not vaccinated, anemic mother/caregiver and small size at birth while not improved sanitation, no iron pills taken, no drugs for intestinal parasites taken and no formal education were not significant.

Discussion

This study utilized data from NDHS conducted in 2018 to examine the spatial variation and predictors of the CAS among 6-59 months aged children in urban and rural areas of Nigeria. With a total of 2,956 children having anemia and stunting concurrently, the overall prevalence rate of 29.2% is high compared to the rate observed in India-21.5% (Gosdin *et al*., 2018), Ghana-11.8% (Christian *et al*., 2020), and Ethiopia-23.9% (Mohammed *et al*., 2019) but lower than the rate observed in Burkina Faso- 87.7% (Tran *et al*., 2018). The empirical results confirm that there was no significant difference between the observed and expected frequency of co-occurrence of anemia and stunting in the pooled sample, and for different places of residence. This suggests that the CAS in the study population may have occurred by chance and not due to comparable causal factors similar to results obtained in previous research (Albalak *et al*., 2000; Gosdin *et al*., 2018).

Prevalence of CAS was higher in rural compared to urban areas. Further, 30 states and the FCT recorded higher prevalence in rural areas. This is consistent with the findings in Ethiopia (Mohammed *et al*., 2019) and Ghana (Christian *et al*., 2020). The urban-rural variation could be attributed to access of urban households to better water, sanitation, healthcare, food and nutrient intake as shown in table 1. Previous studies in Nigeria showed that the high prevalence of stunting and anemia in rural areas was due to inadequate iron intake, parasitic infections, household socioeconomic status, wealth index, toilet types and source of drinking water (Ayogu *et al*., 2015; Fagbamigbe *et al*., 2020). The rural-urban disparities highlight the ineffectiveness of government interventions and policies aimed to improve child nutrition and health in rural areas. Hence, the implementation of one-size-fits-all interventions is undesirable, given the existing rural-urban differentials in the provision of social facilities, socio-demographic characteristics and child nutrition.

Findings in this study indicate that various characteristics of the child, mother/caretaker and household are associated with CAS in children aged 6-59 months. Children with average size at birth had lower risk of being anemic and stunted concurrently while those with smaller size had higher risk. This finding is consistent with previous studies that showed that low birth weight due to intrauterine growth retardation during the mother's pregnancy and poor nutrition after birth influence growth during childhood and lead to the development of anemia (Ferri *et al*., 2014; Ntenda, 2019). Similar to findings by Geda *et al*. (2021) and Mohammed *et al*. (2019), significant positive association was found between episode of diarrhea two weeks before the survey and CAS. Children who had diarrhea were more likely to experience anemia and stunting concurrently. Diarrhea has been shown to be an important risk factor for anemia (Semba *et al*., 2008) and stunting (Brander *et al*., 2019) due to micronutrient losses. Diarrhea results in anemia of inflammation which is the second most common cause of iron deficiency anemia (Chaparro and Suchdev, 2019).

In addition, child's age was significantly associated with CAS. Prevalence rate was highest among the children aged 12-23 months in urban areas (24.9%) and 24-35 months in rural areas (44.0%). This suggests that targeted interventions are required for different age groups in urban and rural areas. Male children were more likely to be anemic and stunted simultaneously compared with female children. This is similar to the results obtained in prior studies (Geda *et al*., 2021; Mohammed *et al.,* 2019). For instance, Mohammed *et al.* (2019) found that the odds of CAS was higher among boys compared to girls.

This population-based study revealed that the anemia status of the mother/caregiver was significantly associated with CAS in children. Children whose caregivers were not anemic had lower risk of being anemic and stunted concurrently. Anemia in children has been linked to maternal anemic status. Women who are anemic are likely to have anemic children (Ntenda *et al.*, 2018). Anemia in women suggest lack of access to good nutrition in the household which affect child health during and after pregnancy. Further, exposure of mothers and their children to similar infections such as malaria and diarrhea could lead to anemia and stunting simultaneously in children.

In addition, the reverse relationship between maternal educational level and CAS in children is hardly surprising since children whose caregivers had no formal education constitute the highest proportion of those that reported concurrent anemia and stunting. Children whose caregivers had no formal education were significantly more likely to be anemic and stunted concurrently similar to findings by Mohammed *et al*. (2019). Maternal education influence knowledge of feeding practices, child care, sanitation and hygiene which in-turn affect child health.

Children living in households that obtained drinking water from unimproved sources such as sachet water and unprotected well were more likely to be anemic and stunted simultaneously. Possibly, the unimproved water may be contaminated with coliform bacteria which is significantly associated with stunting (Shrestha *et al*., 2020) and anemia (Yu *et al*., 2020). Although most (56.4%) of the children that were anemic and stunted concurrently were living in households that used unimproved sanitation facilities (pit without slab and no facility), the odds of CAS was lower among this group compared to those in households that use improved sanitation. This result is in contrast to the finding by Mohammed *et al*. (2019). The finding in this study could be explained by high (27.8%) prevalence of concurrent anemia and stunting among children living in households using pit latrine with a slab which is the most common type of improved sanitation facility in the country. Poor disposal of child's stool and hand washing could expose children to faecal ingestion which causes diarrhea, environmental enteropathy and intestinal worm infection resulting in anemia and stunting (UNICEF, 2014).

The risk of children being anemic and stunted simultaneously consistently reduced with household wealth status. Children in households with poorest wealth status had the highest risk of CAS while those in richest households had the lowest risk. Similar result was obtained by Mohammed *et al*. (2019 and Christian *et al*. (2020). This finding suggest that household wealth is a critical factor influencing child health outcomes. Household access to food, child care, feeding practices, health services, education, improved water and sanitation are determined by their wealth status.

With regards to region of residence, risk of CAS was significantly higher in North West zone compared with the South South zone. This confirms the results of the spatial analysis indicating the location of hotspot cluster in the zone. Access to health insurance in households was found to be a significant predictor of co-occurrence of anemia and stunting in rural areas. Children in households without access to health insurance were more likely to be anemic and stunted simultaneously. Possibly, household health insurance may increase utilization of medical services and improve child health outcomes. Participation in community-based health insurance scheme is associated with reduction in stunting (Nshakir-Rukundo *et al*., 2020) and anemia (Anaba *et al*., 2020) in children.

Another significant finding is the widespread spatial variation of the prevalence of CAS across the 36 states and FCT. States in the North West zone recorded very high prevalence rates. In these states, prevalence rate was high in both rural and urban areas. These states equally had high proportion of children that were anemic and stunted. In addition, the positive spatial autocorrelation indicated clustering of districts with similar prevalence rates, that is, districts with high prevalence rates next to high and those with low rates next to low, as confirmed in the clustering patterns (figure 2). This indicates relative spatial evening of the prevalence of CAS.

The location of hotspot cluster of five states in the North West (Sokoto, Zamfara, Katsina, Kano, Jigawa) and one district in the North East zone (Bauchi) is an important outcome of the cluster analysis. A high proportion of households in the North West and North East zones obtain drinking water from unimproved sources, they utilize unimproved sanitation facilities, are mostly of the poorest wealth quintile and most of the women have no formal education. Further, these states have the highest proportion of children with severe anemia and those that are stunted (NPC and ICF, 2019). These factors could explain the emergence of hotspots in these states.

The GWPR model with fixed Gaussian kernel used to determine variability of factors that explain the spatial variation of CAS performed better than the global Poisson model. Although all the variables are significant in the GPR model, findings from the GWPR model revealed that the explanatory variables are non-stationary. Parameter estimates of not improved water, still breastfeeding, child not vaccinated, anemic caregiver, and child's small size were significantly associated with the variation of CAS in all the states. This suggest that provision of improved source of drinking water, vaccination of children, improved caregiver's nutrition during pregnancy and after delivery will reduce the prevalence of CAS in all the states.

The variable not improved water was significant in all the states suggesting that it is associated with the prevalence of CAS in all the states. Proportion of children with CAS whose household obtained drinking water from non-improved sources was high in the north particularly Kano (12.4%) and Katsina (8.4%) states. Safe and improved source of water supply is required in all the states. Non-vaccination of children was significantly associated with the variation of CAS. Children with incidence of anemia and stunting concurrently that were not vaccinated were mostly in Zanfara (13.5%) and Katsina (13.2%) states. Since infectious diseases attack red blood cells (Takele *et al*., 2021), non-vaccination predisposes children to diseases which may lead to co-occurrence of anemia and stunting.

Similar to the result from logistic regression analysis, child still breastfeeding was significantly associated with the distribution of CAS. Exclusive breastfeeding is recommended by WHO for the first six months for infants. In developing countries, exclusive breastfeeding after six months increases the risk of anemia (Meinzen-Derr *et al*., 2006). Proportion of children with CAS that were still breastfeeding ranged from 0.3% in Bayelsa state to 11.3% in Kano state. Possibly, children that were still breastfeeding were not fed adequately with alternative diets leading to CAS.

The distribution of anemic caregivers is significantly associated with the spatial variation of CAS. Proportion of children with CAS whose caregivers are anemic was high in the North West zone particularly in Kano (14.7%) and Kaduna (7.9%) states. Poor feeding practices of caregivers could also affect children. In addition, small size of child at birth significantly determined variation of CAS. Kaduna (14.5%), Jigawa (13.45) and Kano (9.0%) had high proportion of children with small size at birth. As noted earlier, poor growth during mother's pregnancy and after birth lead to anemia and stunting in children.

The use of large nationally representative sample size is the main strength of this study. This made it possible to determine precisely the prevalence rate of CAS among children aged 6-59 months across the country. Although this study contributes to the understanding of the spatial variation of CAS in Nigeria and other developing countries, it has some limitations. Cross-sectional survey design method was used to obtain the data used in this study. Hence, information provided by respondents could be affected by recall bias. The direction of causality between CAS and the predictor variables could not be determined due to the use of cross-sectional data. Analysis of the spatial pattern was limited to the state level because the number of clusters in urban and rural areas is high.

Findings in this study have imperative policy implications for households, health agencies, government and policymakers. Health agencies and government need to implement and strengthen nutrition-specific interventions that will improve child and maternal health outcomes through micronutrient supplementation. Improved source of drinking water, sanitation facilities and insecticide treated bed nets are necessary in households to protect children and their caregivers from diseases. Government needs to increase food production in rural areas and increase access to food in urban areas. Local and state governments need to implement poverty reduction programs so as to improve household livelihoods. Policymakers, government, households and religious groups need to encourage educational development of girls and women of reproductive age groups so as to improve child care and feeding practices.

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