Anemia prevalence and its predictors among children under-five years in Ghana. A multilevel analysis of the 2019 Ghana malaria indicator survey

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Abstract

Despite the implementation of anemia control interventions in Ghana, prevalence of anemia is still high in children under-five years although it has reduced by 24% between 2008 and 2019. Further reducing the prevalence of anemia requires identifying and targeting critical risk factors associated to anemia. This study seeks to identify predictors of anemia among children under-five years in Ghana. Data from 2019 Ghana MIS was analyzed using both fixed and random effect logistic regression models. Among the 2434 children under-five years, 54% (95% CI 52.0, 57.0) of them were anemic. In the multivariable multilevel model, the risk of anemia was found to be higher in younger children, children who had malaria, children whose mothers were not covered for health insurance, adolescent mothers', non-Christian mothers and poorer households. Significant unobserved community level effects in anemia prevalence were observed. We observed high prevalence of anemia in children under-five and critical risk factors at the child, household, and community levels in this population of children. Multifaceted and targeted approaches are needed to help reduce the anemia prevalence in this setting so as to achieve multiple SDGs which are related to risk and prevalence of anemia by 2030.

Introduction

Anemia in children under-five years although preventable, is a severe public health problem which is closely related to achieving multiple United Nation's Sustainable Development Goals (SDGs) [1–3]. Despite the numerous interventions and control plans such as intermittent iron supplication and food fortification that has been implemented, anemia prevalence (42.6%) and deaths of (45% of children deaths) children under-five years globally remains high [4–10]. However, in the WHO African region the prevalence of anemia is estimated to be 68% among children under-five years [11, 12]. In sub-regions where malaria is endemic the prevalence of anemia is higher (49%-76%) compared to non-endemic malaria regions [13–15].

Reducing the incidence of anemia is essential for improving the health and well-being of populations around the world especially in Asia and Africa where it is most prevalent [3, 16, 17]. Anemia may be cause by vitamin deficiency, iron deficiency, sickle cell anemia, haemolytic anemia, aplastic anemia or anemia of chronic disease[18, 19]. Anemia during pregnancy has both maternal and foetal consequences of which a newly born may suffer from reduced iron store problem from birth up to infancy and the demand for iron during the period of rapid growth [2, 9, 20, 21]. Also, during pregnancy and lactation there is an increasing need for iron, vitamins and minerals by these groups of women, the lack of it makes them and children under-five years the most vulnerable to anemia [21–23].

Although most mothers have been sensitized on the consequences of iron deficiency during antenatal and postnatal clinics, poverty, poor socio-economic challenges, household food insecurity, monotonous diet hinder them from eating healthy meals resulting to anemia [7]. Also, mothers who do not visit antenatal/postnatal clinic, mothers' level of education, diarrhoea, malaria, fever, parasitic infestations, poor sanitation and maternal anemia are other circumstances that leads to anemia [1, 24–26].

Studies have proven that the factors leading to anemia are multifactorial and context-dependent[21]. The contribution of these determinants to childhood anemia are complex and vary from country, dietary practice and environmental factors [27, 28]. For international bodies, governments and other stakeholders to be guided and know the appropriate interventions to implement in Ghana, country specific predictors of anemia in children under-five years must be ascertained [29]. However, to the best of our knowledge, we are yet to come across any study in Ghana using a novel multilevel model to assess country specific potential predictors of anemia, and to quantify possible unobserved community level differences in anemia prevalence in the country. Therefore, this study seeks to determine the predictors of anemia in children under 5 in Ghana utilizing novel multilevel modelling framework.

Methods

Study Design and Participants

Secondary data from the 2019 Ghana Indicator Malaria Survey (GMIS) which was collected as part of the most recent phase of Ghana Demographic and Health Survey (GDHS) was used for this study [30]. Demographic and Health Survey (DHS) which is nationally representative uses a two-stage stratified sampling design method by using enumeration areas from the most current Ghana census data. A total of 200 clusters (103: rural and 97 urban) were used [31]. The survey provided information on all 10 regions in Ghana at the time, although the regions have now been sub-divided to be 16. Because the administrative boundaries of the additional 6 newly created regions were not available at the time of conducting 2019 GMIS, the 10 regions were used [30].

Study Area

The study used data from 2019 Ghana Malaria Indicator Survey. The children recode data file which was part of the 2019 GMIS was used for the analysis of this study.

Sample Size

Total observations (3004) realized for the 2019 GMIS children recode data file was used. However, since the study focused on assessing predictors of anemia in children under-five years, only data on these children (2434) with available anemia status were included in the study representing 81.0% of the original sample [30].

Study Variables

Outcome variable

Anemia among children under-five defined as children with haemoglobin below 11.0 g/dl was the study outcome. Haemoglobin level was dichotomized to 0 if child had haemoglobin level of 11.0 g/dl and above and 1 if child had haemoglobin level below 11.0 g/dl.

Independent variables

The independent variables can be put into three main groups namely, child characteristics, mother or caregiver characteristics and the household characteristics. The child characteristics included sex of child (male or female), age in years (0 through 4), type of birth (single or multiple) birth order (1st, 2nd or 3rd + child), preceding birth interval in months (< 18months, 18 + months or 1st born), experience of fever in the past 2 weeks (no fever, fever with negative malaria test and fever with positive malaria test, fever with unknown malaria test). Mother or caregiver characteristics included age group in years (15–19, 20–29, 30–39 and 40–49 years), parity (1 child, 2–3 children, 4–5 children and 6 + children), highest education (No education, primary, secondary and higher), literacy level of mother (cannot read at all, able to read only parts of sentence or able to read whole sentence), religion (catholic/Christians, Islam, or Others (traditional, none etc.)), ethnicity (Akan, Ewe, Mole-Dagbani, Others ethnicity), Number of births om last five years (1, 2, or 3 + births) and access to health insurance (No access, registered but not covered or registered and covered). Household characteristics included region of residence, place of residence (rural or urban), age group of household head in years (< 30, 30–39, 40–49, 50–59 or 60+), sex of household head (male or female), type of cooking fuel (non-solid fuel or solid fuel), floor material (improved or unimproved material), wall material (improved or unimproved material), roof material (improved or unimproved material), source of drinking water (improved or unimproved source), toilet facility (improved or unimproved facility) and household wealth quintile (poorest, poor, middle, rich or richest). These variables have been shown to be significant factors associated with anemia in literature [7, 12, 27, 32]. Re-categorization of some selected variables from the original survey variables are presented in Table 1.

Table 1
Description of the recoded study variables

Variable name & category	Original categories
Religion	
Catholic/Christians	Catholic, Anglican, Methodist, Presbyterian, Pentecostal/ Charismatic, Other Christians.
Islam	Islam
Others (Trad. / None etc)	Traditional/Spiritualist, No Religion, Other
Ethnicity	
Akan	Akan
Ewe	Ewe
Mole-Dagbani	Mole-Dagbani
Others	Ga/Dangme, Guan, Grusi, Gurma, Mande, Other
Cooking fuel	
Non-solid	Electricity, LPG, natural gas, biogas
Solid	Charcoal, wood, straw/shrubs/grass, agricultural crop
Household floor material	
Unimproved material	Earth/sand, dung, wood planks
Improved material	Parquet or polished wood, vinyl or asphalt strips, ceramic/marble/porcelain tiles/terrazzo, cement, woolen carpet/synthetic carpet, linoleum/rubber carpet
Household wall material	
Unimproved material	No walls, cane/palm/trunks, mud/landcrete, bamboo with mud, stone with mud, plywood, cardboard, reused wood
Improved material	Cement, stone with lime/cement, bricks, cement blocks, wood planks/shingle
Household roof material	
Unimproved material	No roof, thatch/palm leaf, sod, rustic mat, palm/bamboo, wood planks
Improved material	Zinc/aluminium, ceramic/brick tiles, cement, roofing shingles, asbestos/slate roofing sheets
Source of drinking water	
Unimproved source	Unprotected well, unprotected spring, river/dam/lake/ponds/stream/canal/irrigation channel, rainwater, tanker truck, cart with small tank

Variable name & category	Original categories
Religion	
Improved source	Piped into dwelling, piped to yard/plot, piped to neighbour, public tap/standpipe, tube well or borehole, protected well, protected spring, bottled water, sachet water
Type of toilet facility	
Unimproved facility	Flush to somewhere else, flush, don't know where, pit latrine with slab, pit latrine without slab/open pit, no facility/bush/field, hanging toilet/latrine, other
Improved facility	Flush to piped sewer system, flush to septic tank, flush to pit latrine, flush, bio-digester (biofil), ventilated improved pit latrine (VIP), composting toilet

<<< Table 1 **Description of the recoded study variables >>>**

Statistical analysis

Stata SE version 17 (Stata Corp, College Station, TX, USA) was used to perform the statistical analysis. Descriptive analysis was performed using the frequency and both unweighted and weighted percentages for categorical variables. All analysis thereafter were weighted and accounted for clustering, stratification and design effect using the survey mode in Stata ("*svy*") due to the complex survey design of the MIS data. The prevalence of anemia was estimated with the corresponding 95% confidence interval estimates across the categories of all the independent variables considered in the study. The simple Poisson regression model was used to assess the difference in prevalence ratios of anemia across the categories of the exposure variables. Estimates of anemia prevalence across regions and by rural and urban residence as well as study clusters was presented in the form of choropleth maps generated using the Quantum Geographic Information System (QGIS) version 3.28.2.

The binary logistic regression model was used to assess the factors associated with anemia prevalence among the children under-five years. First the crude odds ratio was estimated with the corresponding 95% CI and p-values from the simple logistic regression model. Next the single level fixed effect multivariable logistic regression model was fitted for variables considered in the simple logistic regression analysis. Finally, we extend the single level multivariable logistic regression model to random intercept and random slope multilevel logistic regression model and estimated the odds ratios and their corresponding 95% CI and p-values. The individual child served as level one and community as level 2. We hypothesized that the effect of the rural-urban variable will vary from one community to another, hence the random slope model. Multicollinearity was assessed for all variables considered in the study using variance inflation factor (VIF) and VIF < 10 was considered acceptable. The Hosmer-Lemeshow goodness of fit test was applied to examine how well the model fits the data. The area under the operating characteristics curve (AUROCC) was determined and plotted for both the single level multivariable logistic regression and the multilevel logistic regression models. All statistical analysis were considered significant at *p*-value < 0.05.

Ethical approval and consent to participate

This study was based on publicly available dataset from the MEASURE DHS program. No ethical approval was needed since it did not directly involve contacts between the authors and the individuals interviewed. However, the protocol for the 2019 Ghana Malaria Indicator Survey was approved by the Ghana Health Service Ethical Review Committee and ICF's Institutional Review Board. The risk and benefits of participation in the survey were explained to respondents, including informed consent for the interview or blood collection, and informed consent was sought from all respondents. Also, the data used for this study has no contact details of the interviewed participants and households, and permission was sought from and given by the MEASURE DHS program for this study via the online portal http://www.dhsprogram.com.

Results

Characteristics of study population

From the dataset using the weighed percentages, children under-five years whose anemia status was available were 2434 with 50.9% being males. Multiple birth was 2.6% and two-third (67.8%) were the first child. Majority of the children (88.8%) had no fever in the two-weeks prior to survey interview whilst 7.5% had fever with malaria positive test. Young mothers (20–29) were more (44.6%) than mothers in other age groups with about 27.5% of the women having between 4 to 5 children. However only 5.2% of the mothers had attained higher educational status and 54.2% cannot read at all. Children aged 2 years were more than children of other ages, they represented 23.8% of the study population. However, most (58.9%) of them lived in rural areas. Although majority of study participants (23.4%) lived in poorest household with household heads mostly being males (70.2%), about 87.8% had improved water source and 57.7% had unimproved toilet facilities in their homes/ community. Two weeks prior to the survey, 7.5% of the children under-five years tested positive for malaria (Table 2).

Table 2
Characteristics of study participants and prevalence of anemia among children under-five years

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
Overall	2434 (100.0)	100	54.5 [52.0, 57.0]	
Child characteristics				
Sex of child				0.194
Male	1236 (50.8)	50.9	56.4 [52.9, 59.8]	
Female	1198 (49.2)	49.1	52.6 [48.6, 56.6]	
Age group of children				< 0.001
6–11 months	305 (12.5)	11.9	66.7 [59.9, 72.9]	
12–23 months	565 (23.2)	23.5	62.9 [57.8, 67.8]	
24–35 months	554 (22.8)	23.8	59.2 [54.2, 64.0]	
36–47 months	521 (21.4)	21.2	50.1 [45.2, 55.0]	
48–59 months	489 (20.1)	19.7	36.3 [31.6, 41.3]	
Type of birth				0.584
Single birth	2358 (96.9)	97.4	54.4 [51.9, 56.9]	
Multiple birth	76 (3.1)	2.6	58.3 [43.8, 71.4]	
Birth order				< 0.001
1st child	1675 (68.8)	67.8	49.5 [46.6, 52.4]	
2nd child	690 (28.3)	29.2	65.2 [61.1, 69.1]	
3rd + child	69 (2.8)	3.0	65.9 [52.3, 77.2]	
Preceding birth interval (months)				< 0.001
<18 months	52 (2.1)	2.3	57.0 [40.8, 71.7]	
18 + months	707 (29.0)	29.9	65.9 [61.5, 70.0]	

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
1st born	1675 (68.8)	67.8	49.5 [46.6, 52.4]	
Fever with malaria in the past 2 weeks				< 0.001
No fever	2105 (86.5)	88.8	53.2 [50.4, 55.9]	
Yes, negative malaria	69 (2.8)	2.4	56.7 [42.5, 69.9]	
Yes, positive malaria	218 (9.0)	7.5	67.4 [58.8, 75.0]	
Yes, unknown results	42 (1.7)	1.3	70.9 [53.8, 83.6]	
Mother/caregiver characteristics				
Age group of mothers				0.001
15–19	90 (3.7)	3.3	71.1 [60.3, 79.9]	
20–29	1092 (44.9)	44.6	55.2 [51.8, 58.5]	
30–39	976 (40.1)	41.4	53.8 [50.1, 57.6]	
40–49	276 (11.3)	10.7	49.4 [42.0, 56.8]	
Parity of mother				0.001
One child	391 (16.1)	16.2	53.1 [47.5, 58.6]	
2–3 children	987 (40.6)	42.0	50.8 [47.0, 54.7]	
4–5 children	674 (27.7)	27.5	56.5 [51.6, 61.3]	
6 + children	382 (15.7)	14.3	63.3 [57.7, 68.5]	
Highest education				< 0.001
No education	698 (28.7)	22.9	63.4 [58.7, 67.9]	
Primary	531 (21.8)	21.9	61.5 [55.2, 67.5]	
Secondary	1097 (45.1)	50.0	48.9 [45.4, 52.4]	

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
Higher	108 (4.4)	5.2	40.3 [31.5, 49.7]	
Literacy level of mother				< 0.001
Cannot read at all	1428 (58.7)	54.2	60.0 [56.5, 63.4]	
Able to read only parts of sentence	179 (7.4)	7.7	53.7 [45.4, 61.9]	
Able to read whole sentence	827 (34.0)	38.2	47.0 [43.1, 50.9]	
Religion of mother				< 0.001
Catholic/Christians	1724 (70.8)	74.3	50.4 [47.6, 53.2]	
Islam	591 (24.3)	21.8	66.0 [60.7, 70.9]	
Others (Trad. / None etc)	119 (4.9)	3.9	69.4 [59.9, 77.6]	
Ethnicity of mother				< 0.001
Akan	822 (33.8)	40.4	47.9 [43.8, 52.1]	
Ewe	307 (12.6)	15.1	53.7 [46.8, 60.6]	
Mole-Dagbani	807 (33.2)	22.4	67.2 [62.1, 72.0]	
Others	498 (20.5)	22.1	54.3 [49.7, 58.8]	
Births in the last five years				0.132
1	1373 (56.4)	56.2	53.1 [50.0, 56.2]	
2	948 (38.9)	38.2	57.4 [53.4, 61.2]	
3+	113 (4.6)	5.6	49.6 [39.6, 59.6]	
Access to health insurance				0.002
Not registered	255 (10.5)	10.8	60.0 [53.1, 66.4]	
Registered, not covered	922 (37.9)	37.9	58.6 [54.9, 62.1]	

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
Registered, covered	1257 (51.6)	51.3	50.4 [46.8, 54.1]	
Household characteristics				
Region of residence				< 0.001
Western	243 (10.0)	10.7	52.2 [46.6, 57.7]	
Central	216 (8.9)	7.2	64.4 [53.6, 73.9]	
Greater Accra	174 (7.1)	12.6	42.6 [35.7, 49.7]	
Volta	212 (8.7)	11.2	56.2 [51.1, 61.2]	
Eastern	189 (7.8)	9.9	44.4 [35.4, 53.8]	
Ashanti	251 (10.3)	16.6	44.8 [39.1, 50.6]	
Brong Ahafo	236 (9.7)	9.1	59.0 [51.6, 66.0]	
Northern	407 (16.7)	15.1	68.1 [62.3, 73.3]	
Upper east	236 (9.7)	4.3	73.0 [65.0, 79.7]	
Upper west	270 (11.1)	3.3	61.9 [56.0, 67.4]	
Place of residence				< 0.001
Urban	912 (37.5)	41.1	48.0 [44.4, 51.6]	
Rural	1522 (62.5)	58.9	59.1 [55.8, 62.3]	
Household size				< 0.001
2–3 members	314 (12.9)	14.5	46.3 [40.8, 51.9]	
4–6 members	1183 (48.6)	50.4	51.9 [48.8, 55.1]	
7–9 members	618 (25.4)	23.4	60.0 [55.4, 64.6]	
10 + members	319 (13.1)	11.6	65.1 [57.5, 72.0]	

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
Number children under-five in household				0.005
1 child	986 (40.5)	41.4	50.9 [47.6, 54.2]	
2 children	955 (39.2)	38.4	55.3 [50.8, 59.7]	
3 children	319 (13.1)	13.4	58.2 [49.7, 66.3]	
4 children	174 (7.1)	6.8	65.0 [56.4, 72.8]	
Age of household head				0.623
<30	378 (15.5)	16.2	54.3 [49.2, 59.2]	
30–39	806 (33.1)	35.8	52.4 [48.4, 56.4]	
40–49	599 (24.6)	23.6	55.3 [49.4, 61.1]	
50–59	295 (12.1)	11.3	57.2 [50.7, 63.4]	
60 + years	356 (14.6)	13.0	57.1 [50.5, 63.5]	
Sex of household head				0.558
Male	1779 (73.1)	70.2	55.0 [52.0, 58.0]	
Female	655 (26.9)	29.8	53.4 [49.0, 57.8]	
Type of cooking fuel				< 0.001
Non-solid fuel	316 (13.0)	17.4	39.8 [34.0, 45.8]	
Solid fuel	2118 (87.0)	82.6	57.7 [54.7, 60.6]	
Household floor material				0.037
Unimproved material	256 (10.5)	8.8	61.9 [54.1, 69.1]	
Improved material	2178 (89.5)	91.2	53.8 [51.2, 56.4]	
Household wall material				< 0.001

	Unweighted	Weighted	Prevalence of anemia	
Characteristics	**n (%)**	**%**	**% [95% CI]**	**P-value**
Unimproved material	662 (27.2)	21.1	64.5 [59.8, 68.9]	
Improved material	1772 (72.8)	78.9	51.9 [49.2, 54.6]	
Household roof material				< 0.001
Unimproved material	136 (5.6)	4.3	66.7 [59.8, 72.8]	
Improved material	2298 (94.4)	95.7	54.0 [51.4, 56.5]	
Source of drinking water				0.002
Unimproved source	357 (14.7)	12.2	65.3 [57.6, 72.2]	
Improved source	2077 (85.3)	87.8	53.1 [50.3, 55.8]	
Type of toilet facility				< 0.001
Unimproved facility	1563 (64.2)	57.7	60.1 [56.8, 63.4]	
Improved facility	871 (35.8)	42.3	46.9 [43.4, 50.4]	
Household wealth quintile				< 0.001
Poorest	810 (33.3)	23.4	68.5 [64.7, 72.1]	
Poorer	511 (21.0)	21.6	59.2 [53.8, 64.4]	
Middle	479 (19.7)	21.1	54.6 [48.4, 60.7]	
Richer	347 (14.3)	18.0	48.2 [41.9, 54.7]	
Richest	287 (11.8)	15.8	34.6 [28.9, 40.9]	

<<< Table 2: **Characteristics of study participants and prevalence of anemia among children under-five years >>>**

Prevalence Of Anemia

The anemia prevalence of children under-five years in Ghana was 54.5% (95% CI 52.0, 57.0) with 59.1% in rural areas and 41.1% in Urban areas (Table 2). The Upper East region recorded the highest (73.0%), followed by

Northern region (68.1%) prevalence of anemia in children under-five years in Ghana whilst Greater Accra region recorded the least prevalence (42.6%) of anemia in the study population. In terms of the stratification to rural and urban areas within regions, the anemia was highest in the rural areas of the Upper West region (79.1%) followed by the Brong Ahafo (57.3%), the Ashanti (56.9%) and the Upper East (53.4%) regions whilst anemia highest the urban areas of the Eastern (71.8%), Upper East (70.4%) and the Northern (70.6%) regions. Figure 1D shows the spot map of the prevalence of anemia at the cluster level (Fig. 1).

<<< Fig. 1: **Prevalence of anemia at the regional (A), rural (B), urban (C) and cluster (D) levels in Ghana >>>**

Infants were more likely to be anemic (66.7%) compared to other children below 5 years. Children who tested positive to malaria were more likely to be anemic compared to children who had no fever, or no malaria two weeks prior to the survey (67.4%; at 95% CI 58.8, 75.0; $p < 0.01$). Teenage mothers (20–29 years) recorded a higher prevalence of anemia in their children compared to children of younger and older mothers (71.1%; at 95% CI 60.3–79.9; $p < 0.01$). Anemia was higher (63.3%) in children under-five years of mothers who had more than six children. Mothers who had never been educated had a higher prevalence (63.4%) of their children having anemia than mothers who had attained higher education (40.3%). Children who were neither registered nor covered on any health insurance scheme attained a higher prevalence of anemia (60.0%) than children who were registered and covered (50.4%). Also, children for very poor households, unimproved toilet facilities and unimproved water facilities were more likely to be anemic, 68.5%, 60.1% and 65.3% respectively than children from richer (34.6%), improved toilets (46.9%) and improved water facilities (53.1%) (Table 2).

Factors Associated With Anemia In Children Under-five From The Multilevel Model

The results from the single multivariable logistic regression and the multilevel regression analyses were presented in Table 3. All the model comparison statistics such as the AIC, BIC and AUROC value favoured the multilevel logistic regression models over the single level multivariable logistic regression model. Among the multilevel models, the random intercept model was preferred to the random slope model because it has the lowest AIC and BIC, and negligible differences in the AUROC value under the principle of parsimony (Table 3, Fig. 2). Thus, the results showed that the random intercept multilevel logistic regression model was superior to the random slope multilevel multivariable logistic regression model. As a result, the interpretations and conclusions were based on the results from the random intercept multilevel logistic regression model.

Table 3
Binary logistic regression model of the factors associated with anemia among children under-five years old in Ghana.

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Sex of child								
Male	1.16 [0.93, 1.46]	0.192	1.20 [1.07, 1.35]	0.002	1.20 [1.07, 1.36]	0.003	1.20 [1.07, 1.36]	0.002
Female	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Age group of children								
6–11 months	3.51 [2.37, 5.20]	< 0.001	3.47 [2.47, 4.86]	< 0.001	3.59 [2.54, 5.08]	< 0.001	3.60 [2.54, 5.09]	< 0.001
12–23 months	2.98 [2.24, 3.96]	< 0.001	2.86 [1.97, 4.13]	< 0.001	2.97 [2.08, 4.23]	< 0.001	2.97 [2.07, 4.27]	< 0.001
24–35 months	2.55 [1.88, 3.46]	< 0.001	2.60 [1.85, 3.66]	< 0.001	2.61 [1.82, 3.74]	< 0.001	2.61 [1.83, 3.74]	< 0.001
36–47 months	1.76 [1.32, 2.35]	< 0.001	1.77 [1.29, 2.43]	< 0.001	1.80 [1.32, 2.46]	< 0.001	1.79 [1.30, 2.47]	< 0.001
48–59 months	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Type of birth								
Single birth	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Multiple birth	1.17 [0.65, 2.10]	0.600	1.14 [0.57, 2.30]	0.710	1.18 [0.59, 2.36]	0.647	1.18 [0.58, 2.39]	0.642
Birth order								
1st child	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
2nd child	1.91 [1.58, 2.32]	< 0.001	1.41 [1.13, 1.75]	0.003	1.40 [1.12, 1.75]	0.003	1.40 [1.12, 1.75]	0.003
3rd + child	1.97 [1.09, 3.55]	0.024	1.36 [0.70, 2.64]	0.371	1.32 [0.65, 2.71]	0.441	1.33 [0.65, 2.71]	0.438
Fever with malaria in the past 2 weeks								
No fever	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Yes, negative malaria	1.15 [0.64, 2.07]	0.631	1.15 [0.56, 2.38]	0.700	1.16 [0.55, 2.43]	0.691	1.16 [0.55, 2.44]	0.701
Yes, positive malaria	1.82 [1.24, 2.69]	0.003	1.48 [1.12, 1.96]	0.006	1.53 [1.13, 2.06]	0.006	1.52 [1.13, 2.05]	0.006
Yes, unknown results	2.15 [1.03, 4.49]	0.042	1.73 [0.91, 3.32]	0.096	1.74 [0.91, 3.34]	0.096	1.75 [0.90, 3.40]	0.097
Age group of mothers								
15–19	2.52 [1.43, 4.45]	0.002	2.31 [1.42, 3.75]	0.001	2.21 [1.36, 3.57]	0.001	2.21 [1.36, 3.58]	0.001
20–29	1.26 [0.93, 1.71]	0.129	1.50 [0.99, 2.26]	0.053	1.47 [0.96, 2.25]	0.074	1.48 [0.97, 2.26]	0.067
30–39	1.20 [0.86, 1.66]	0.280	1.38 [0.96, 1.99]	0.082	1.37 [0.95, 1.98]	0.095	1.37 [0.96, 1.97]	0.083
40–49	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Parity of mother								
One child	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
2–3 children	0.91 [0.69, 1.21]	0.525	0.90 [0.63, 1.29]	0.576	0.90 [0.63, 1.28]	0.558	0.90 [0.63, 1.28]	0.556
4–5 children	1.15 [0.86, 1.54]	0.353	1.07 [0.68, 1.66]	0.778	1.03 [0.66, 1.62]	0.889	1.03 [0.66, 1.60]	0.899
6 + children	1.52 [1.09, 2.13]	0.014	1.33 [0.91, 1.95]	0.142	1.31 [0.90, 1.91]	0.162	1.30 [0.89, 1.89]	0.171
Highest education								
No education	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Primary	0.92 [0.65, 1.32]	0.652	1.27 [0.92, 1.76]	0.150	1.30 [0.92, 1.82]	0.131	1.29 [0.92, 1.81]	0.137
Secondary	0.55 [0.43, 0.70]	< 0.001	0.95 [0.63, 1.44]	0.803	0.97 [0.63, 1.50]	0.892	0.96 [0.62, 1.48]	0.859
Higher	0.39 [0.26, 0.58]	< 0.001	1.15 [0.63, 2.10]	0.651	1.20 [0.62, 2.32]	0.589	1.20 [0.61, 2.35]	0.596
Literacy level of mother								

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Cannot read at all	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Able to read only parts of sentence	0.77 [0.55, 1.09]	0.137	1.06 [0.74, 1.54]	0.742	1.06 [0.72, 1.56]	0.756	1.07 [0.72, 1.58]	0.732
Able to read whole sentence	0.59 [0.47, 0.74]	< 0.001	1.04 [0.68, 1.58]	0.860	1.03 [0.67, 1.59]	0.896	1.03 [0.67, 1.60]	0.892
Religion of mother								
Catholic/Christians	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Islam	1.91 [1.47, 2.48]	< 0.001	1.53 [1.17, 1.99]	0.002	1.53 [1.17, 2.00]	0.002	1.53 [1.18, 1.98]	0.001
Others (Trad. /None etc)	2.23 [1.44, 3.47]	< 0.001	1.64 [1.09, 2.47]	0.017	1.61 [1.06, 2.45]	0.027	1.61 [1.06, 2.45]	0.027
Ethnicity of mother								
Akan	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Ewe	1.26 [0.90, 1.77]	0.180	1.14 [0.86, 1.51]	0.377	1.20 [0.88, 1.63]	0.253	1.20 [0.87, 1.65]	0.260
Mole-Dagbani	2.23 [1.68, 2.96]	< 0.001	1.39 [0.89, 2.17]	0.149	1.45 [0.91, 2.31]	0.117	1.47 [0.89, 2.43]	0.129
Others	1.29 [1.01, 1.65]	0.041	0.88 [0.64, 1.21]	0.417	0.88 [0.63, 1.22]	0.445	0.88 [0.64, 1.22]	0.452
Births in the last five years								
1	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
2	1.19 [0.98, 1.43]	0.071	1.15 [0.84, 1.57]	0.399	1.17 [0.85, 1.62]	0.341	1.17 [0.85, 1.62]	0.340
3+	0.87 [0.57, 1.33]	0.514	0.79 [0.43, 1.44]	0.439	0.79 [0.42, 1.48]	0.462	0.79 [0.42, 1.49]	0.469
Access to health insurance								
Not registered	1.47 [1.09, 1.98]	0.012	1.47 [1.14, 1.88]	0.002	1.49 [1.15, 1.93]	0.002	1.49 [1.15, 1.93]	0.002
Registered, not covered	1.39 [1.13, 1.71]	0.002	1.45 [1.21, 1.74]	< 0.001	1.45 [1.21, 1.74]	< 0.001	1.46 [1.23, 1.74]	< 0.001

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Registered, covered	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Region of residence								
Western	0.67 [0.48, 0.94]	0.019	1.35 [0.88, 2.08]	0.172	1.41 [0.90, 2.20]	0.133	1.40 [0.90, 2.19]	0.136
Central	1.11 [0.67, 1.86]	0.675	2.37 [1.36, 4.12]	0.002	2.47 [1.42, 4.29]	0.001	2.52 [1.42, 4.47]	0.002
Greater Accra	0.46 [0.31, 0.67]	< 0.001	1.26 [0.75, 2.12]	0.379	1.32 [0.78, 2.25]	0.300	1.32 [0.78, 2.25]	0.304
Volta	0.79 [0.57, 1.09]	0.151	1.28 [0.87, 1.87]	0.210	1.23 [0.84, 1.79]	0.281	1.25 [0.84, 1.85]	0.278
Eastern	0.49 [0.31, 0.77]	0.002	1.10 [0.67, 1.80]	0.713	1.14 [0.70, 1.86]	0.594	1.13 [0.70, 1.81]	0.626
Ashanti	0.50 [0.36, 0.70]	< 0.001	1.01 [0.65, 1.57]	0.976	1.05 [0.66, 1.67]	0.853	1.04 [0.65, 1.65]	0.867
Brong Ahafo	0.89 [0.60, 1.31]	0.542	1.45 [0.87, 2.43]	0.155	1.48 [0.87, 2.51]	0.145	1.50 [0.87, 2.59]	0.140
Northern	1.31 [0.92, 1.87]	0.128	1.33 [0.87, 2.03]	0.190	1.34 [0.87, 2.05]	0.184	1.37 [0.87, 2.14]	0.170
Upper East	1.66 [1.06, 2.60]	0.026	2.06 [1.27, 3.34]	0.003	2.07 [1.29, 3.32]	0.003	2.03 [1.26, 3.26]	0.004
Upper West	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Place of residence								
Urban	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Rural	1.57 [1.29, 1.91]	< 0.001	1.02 [0.84, 1.23]	0.868	1.00 [0.83, 1.19]	0.964	0.99 [0.83, 1.18]	0.927
Household size								
2–3 members	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
4–6 members	1.25 [0.97, 1.63]	0.086	1.40 [0.96, 2.04]	0.077	1.40 [0.96, 2.06]	0.083	1.41 [0.96, 2.07]	0.076
7–9 members	1.74 [1.34, 2.28]	< 0.001	1.54 [1.05, 2.26]	0.027	1.59 [1.08, 2.33]	0.018	1.60 [1.09, 2.35]	0.017

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
10 + members	2.17 [1.49, 3.14]	< 0.001	1.81 [1.18, 2.78]	0.007	1.92 [1.25, 2.95]	0.003	1.92 [1.25, 2.95]	0.003
Number children under-five in household								
1 child	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
2 children	1.19 [0.96, 1.48]	0.111	0.79 [0.60, 1.03]	0.076	0.78 [0.60, 1.02]	0.066	0.78 [0.60, 1.03]	0.076
3 children	1.34 [0.92, 1.96]	0.122	0.87 [0.55, 1.35]	0.526	0.85 [0.54, 1.35]	0.490	0.85 [0.53, 1.35]	0.485
4 children	1.79 [1.23, 2.60]	0.002	0.76 [0.43, 1.35]	0.352	0.74 [0.41, 1.33]	0.310	0.74 [0.41, 1.35]	0.323
Age of household head								
<30	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
30–39	0.93 [0.72, 1.20]	0.568	1.03 [0.78, 1.35]	0.838	1.05 [0.80, 1.38]	0.741	1.04 [0.79, 1.37]	0.771
40–49	1.04 [0.76, 1.43]	0.794	1.01 [0.74, 1.37]	0.947	1.03 [0.76, 1.39]	0.853	1.02 [0.76, 1.38]	0.879
50–59	1.13 [0.82, 1.55]	0.466	0.92 [0.77, 1.11]	0.403	0.92 [0.77, 1.10]	0.359	0.92 [0.77, 1.10]	0.349
60 + years	1.12 [0.82, 1.54]	0.471	0.82 [0.64, 1.05]	0.117	0.83 [0.65, 1.05]	0.112	0.82 [0.65, 1.05]	0.113
Sex of household head								
Male	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Female	0.94 [0.76, 1.16]	0.555	1.16 [0.85, 1.58]	0.362	1.16 [0.84, 1.59]	0.370	1.15 [0.84, 1.58]	0.378
Household wall material								
Unimproved material	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Improved material	0.59 [0.48, 0.74]	< 0.001	1.07 [0.74, 1.54]	0.724	1.05 [0.73, 1.52]	0.787	1.05 [0.72, 1.53]	0.815

	Adjusted models							
	Unadjusted model		Fixed effect model		Random intercept multilevel model		Random slope multilevel model	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Source of drinking water								
Unimproved source	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Improved source	0.60 [0.42, 0.86]	0.005	0.95 [0.73, 1.25]	0.741	0.93 [0.71, 1.20]	0.559	0.94 [0.72, 1.22]	0.627
Type of toilet facility								
Unimproved facility	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Improved facility	0.59 [0.48, 0.72]	< 0.001	1.04 [0.76, 1.42]	0.830	1.03 [0.75, 1.43]	0.836	1.05 [0.76, 1.46]	0.776
Household wealth quintile								
Poorest	4.11 [2.98, 5.67]	< 0.001	2.80 [1.56, 5.05]	0.001	2.97 [1.63, 5.42]	< 0.001	3.01 [1.64, 5.51]	< 0.001
Poorer	2.74 [2.00, 3.74]	< 0.001	2.36 [1.58, 3.51]	< 0.001	2.52 [1.64, 3.87]	< 0.001	2.56 [1.65, 3.98]	< 0.001
Middle	2.27 [1.54, 3.34]	< 0.001	1.87 [1.31, 2.68]	0.001	1.98 [1.34, 2.93]	0.001	2.03 [1.32, 3.11]	0.001
Richer	1.76 [1.14, 2.72]	0.011	1.68 [1.17, 2.41]	0.005	1.74 [1.19, 2.54]	0.004	1.78 [1.19, 2.64]	0.005
Richest	1.00 [reference]		1.00 [reference]		1.00 [reference]		1.00 [reference]	
Model summary								
AIC			2871.988		2867.826		2869.425	
BIC			2982.136		2977.974		2985.37	
AUROC (95% CI)			0.712 [0.691, .732]		0.729 [0.709, 0.749]		0.730 [0.710, 0.750]	
			Random effect analysis					
Child level variance			$\pi^2/3 \approx 3.29$		$\pi^2/3 \approx 3.29$		$\pi^2/3 \approx 3.29$	

	Adjusted models							
	Unadjusted model		**Fixed effect model**		**Random intercept multilevel model**		**Random slope multilevel model**	
Characteristics	**cOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**	**aOR [95% CI]**	**P-value**
Community level variance (intercept)			-		0.08 (SE = 0.04)		0.13(SE = 0.10)	
Community level variance (slope: rural-urban)			-		-		0.03(SE = 0.12)	
COR: crude odds ratio. AOR: adjusted odds ratio. CI: Confidence interval. SE: Standard error. AIC : Akaike information criteria. BIC : Bayesian information criteria. AUROCC : Area under the operating receiver characteristics curve								

The study found that children in Central (aOR: 2.47 at 95% CI 1.42–4.29; p = 0.001) and Upper East (aOR: 2.07 at 95% CI 1.29–3.32; p = 0.003) regions were 2.47 and 2.07 times more likely to be anemic compared to children who were in Upper West region respectively. Also, male children under-five years were 20% more likely to be anemic compared to female children under-five years (aOR: 1.20 at 95% CI 1.07–1.36; p = 0.003). Infants between 6 and 12 months old were 3.6 times more likely to be anemic compared to children who were 4 years old (aOR: 3.59 at 95% CI 2.54–5.08; p < 0.001). Second born children were 40% more likely to be anemic compared to first born children (aOR: 1.40, 95% CI: 1.12–1.75, p = 0.003). Children born to adolescent mothers had over 2 times high odds of anemia compared to children born to mothers in the age range 40–49 years (aOR: 2.21, 95% CI: 1.36–3.57, p = 0.001).

Additionally, children who tested positive for malaria in the last 2 weeks prior to the survey were 53% more likely to be anemic compared to children who had no malaria (aOR: 1.53 at 95% CI 1.13–2.06; p = 0.006). The odds of anemia among children were 45% and 49% higher for mothers who were registered, but not covered with insurance (aOR: 1.45, 95% CI: 1.21–1.74, p < 0.001) and those who were not registered at all (aOR: 1.49, 95% CI: 1.15–1.93, p = 0.002). Also, children born to poorest households were about 3 times more likely to be anemic than children in richer households (aOR: 2.97 at 95% CI 1.63–5.42; p < 0.001) (Table 3).

Figure 2 showed the predictive ability of the fitted models to correctly predict under-five anemia prevalence among children under-five in Ghana. The predictive ability of the single level model was 71% (69, 73%), 73% (0.71, 0.74%) for the random intercept multilevel model and 73% (0.71, 0.75%) for the random slope multilevel model. Thus, both the random intercept and the random slope multilevel models provided similar predictive ability. However, based on the principle of parsimony, the random intercept multilevel model was preffered.

<<< Fig. 2: **Comparison of the Area under the receiver operating characteristics curve (AUROCC) of the fixed and multilevel effect models for predicting under-five anemia. >>>**

Discussion

This study employed multilevel logistic regression model to determine predictors of anemia among 2434 children under-five years in Ghana. The study found unobserved substantial community level differences in the probability of anemia among this group of children. Thus, the probability of developing anemia differs from one community to another in the country, suggesting the need for targeted community level public health interventions aimed at reducing anemia within communities rather than universal interventions. The risk of anemia was found to be higher in children below two years, male children, children born to adolescent mothers, children born to non-Christian homes, children whose mothers were not covered with health insurance, leaving in either upper west or central region and children born to families of poorer households. Our findings' revealed anemia was prevalent among 54% of children under five, an estimate lower than 76.6% in Sub-Sahara Africa [33] but reasonably higher in other sub-Sahara Africa countries[13, 34] and global estimates of 40.0% in 2019 [16, 35]. Although the World Health Organization considers anemia prevalence greater than 40% as a severe public health problem, findings from this study and another study showed that Ghana's anemia prevalence in children under-five years has reduced from 78% in 2008 to 66% in 2014 and further to 54% in 2019 which implies anemia intervention control programs implemented are gradually influencing the population [36]. This shows that although Ghana's anemia prevalence is lower than most developing countries [37] it is still a severe public health concern which needs specific geographic, behavioral, community and individual interventions to reduce it drastically.

Also, older children (> 2 years) were at a lesser risk of anemia compared to infants as shown in this study. This is in line with several studies that reported on high prevalence among infants and children under two years compared to older children[35, 38]. The higher prevalence of anemia is likely to be the effect of monotonous diets, poor feeding habits during weaning periods worsens the problem of anemia as breast milk is replaced with meals that lack irons, vitamins, and other essential nutrients. Also, during infancy, these children are more vulnerable to diseases because they have less developed immune system, and this makes them more likely to be susceptible to anemia which is largely caused by low level of iron. Although babies are born with iron stored in their bodies, because of their rapid growth, they need to absorb a lot of iron each day. Iron deficiency anemia most commonly affects babies 9 through 24 months old.

Furthermore, our results showed that the risk of anemia when a child has malaria is higher which is consistent with a study by [28, 33, 36, 39]. The main approach to preventing anemia in children under five is through malaria prevention, diagnoses, and treatment [36]. Several studies have confirmed the presence of malaria in children causes severe anemia which may lead cognitive issues and even death [34]. In some parts of Ghana, sanitation issues, vegetation, rainfall, and precipitation contribute to the formation of natural habitats for mosquitoes thereby increasing children's risk of malaria in such regions [35].

A study conducted across multiple countries in sub-Sahara Africa confirms our findings that females were at lower risk of anemia compared to the male child although significant variations was not observed between the two genders in a study analysis of three national demographic health survey data from Ghana [7, 33, 40]. The prevalence of anemia was higher in males than females this is similar in studies conducted by [33, 34, 37, 38, 40] where male children less than 60 months older exhibited a higher fold of being diagnosed with anemia than females. Reasons being male children have a higher pre-natal and post-natal growth [41]. Conversely at puberty anemia is more prevalent in females than males due to menstruation, but that difference couldn't be established in a study elsewhere [40].

Further, our findings of higher risk of anemia among children in poorer households is also supported by multiple literature [33, 42–44]. Children from poorer households may be fed monotonous, competition for food, insufficient meals per day, undernutritious diets which wouldn't contain the essential nutrients to prevent anemia, hence they are being at higher risk of anemia compared to children from richer homes who because of the availability of resources may be fed with right proportions of healthy meals [7].

In addition, increase in household size was found to be associated with increased risk of anemia among children. This is supported by findings from elsewhere in Ethiopia [42] and a systematic review in Africa [13]. Reducing household crowding, improving toilet and water facilities helped in reducing the risk of anemia in children under-five years[34].

Although the univariate analysis showed that anemia was more prevalent in the rural areas compared to the urban areas, both the fixed and multilevel multivariable analysis did not show differentials in anemia prevalence between the rural and urban areas. This finding was also observed in other literature where residence was no longer significant after adjusting for other factors [7]. This suggest that, implementing interventions in just rural areas are not the best approach but instead, it imperative we go further to identify what demographic of children is associated with anemia within these rural areas. This however may not be the same for other settings [42]. In a study by Gebreweld et al, [35] children under five urban dwellers were 1.8 times more likely to be anemic than children under five rural dwellers [35].

Major findings

1. Anemia was prevalent among 54.5% (95% CI: 52.0%-57.0%)
2. Substantial unobserved community level differences exist in anemia prevalence.
3. Anemia was highest among children below two years.
4. Anemia was 50% higher among children with history of malaria in the past two weeks.
5. Anemia was higher among children born to adolescent mothers.
6. Anemia was higher among children to mothers in non-Christian homes.
7. Anemia was over 40% more prevalent among children whose mothers were not covered by health insurance.
8. Anemia was higher among children within households of 7 or more members.
9. Anemia was highest in the Central and Upper East regions.
10. Anemia was higher among children in poorer households compared to richer households.

Study Limitations

The study used a cross-sectional study design hence interpretation of results should be done in the context of association and not causality. Also, given that the measurement was among only children alive at the time of the survey, the results is likely to be biased especially for the exclusion of children who died due to anemia related causes. The data is also limited in terms of availability of other variables that are likely to impact the hemoglobin level such as uptake of iron supplementation, diarrhea among children and others.

Conclusion

Prevalence of anemia among children remains high in Ghana especially among poorer households, infants, and children of younger mothers. As Ghana is assiduously working hard towards achieving majority of the SDGs by 2030, the identified factors in this study could be considered as part of an overall strategy aimed at addressing the anemia problem in the country. Also, the type of intervention and intervention allocation strategies should be reorganized and targeted at communities to attain a reduced prevalence of anemia in children under-five years in the country. Our finding that children from one community were less likely to be anemic compared to children from another community suggest the need to search for other factors not considered in this study that might help to further understand why children from certain communities have had higher chances of being anemic than their counterparts from other communities in this population.

Abbreviations

AUROCC
Area Under the Receiver Operating Characteristics Curve
DHS
Demographic and Health Surveys
GDHS
Ghana Demographic and Health Surveys
GMIS
Ghana Malaria Indicator Survey
QGIS
Quantum Geographic Information System
SDGs
Sustainable Development Goals
VIF
Variance Inflation Factor

Declarations

Data availability

The datasets generated and/or analysed during the current study are available from the MEASURE DHS Program website http://dhsprogram.com/data/available-datasets.cfm.

Author contributions

JMKA developed the concept and secured the data. JMKA and YA analysed the data. JMKA, YA, AEP, JKB, and KMS wrote the first draft manuscript. JMKA, YA, AEP, JKB, and KMS contributed to the writing and reviewing of the various sections of the manuscript. JMKA, YA, AEP, JKB, and KMS reviewed the final version of the manuscript before submission. All authors read and approved the final manuscript.

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Competing Interests

The authors declare no competing interests.

Consent for publication

Not applicable

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Figures

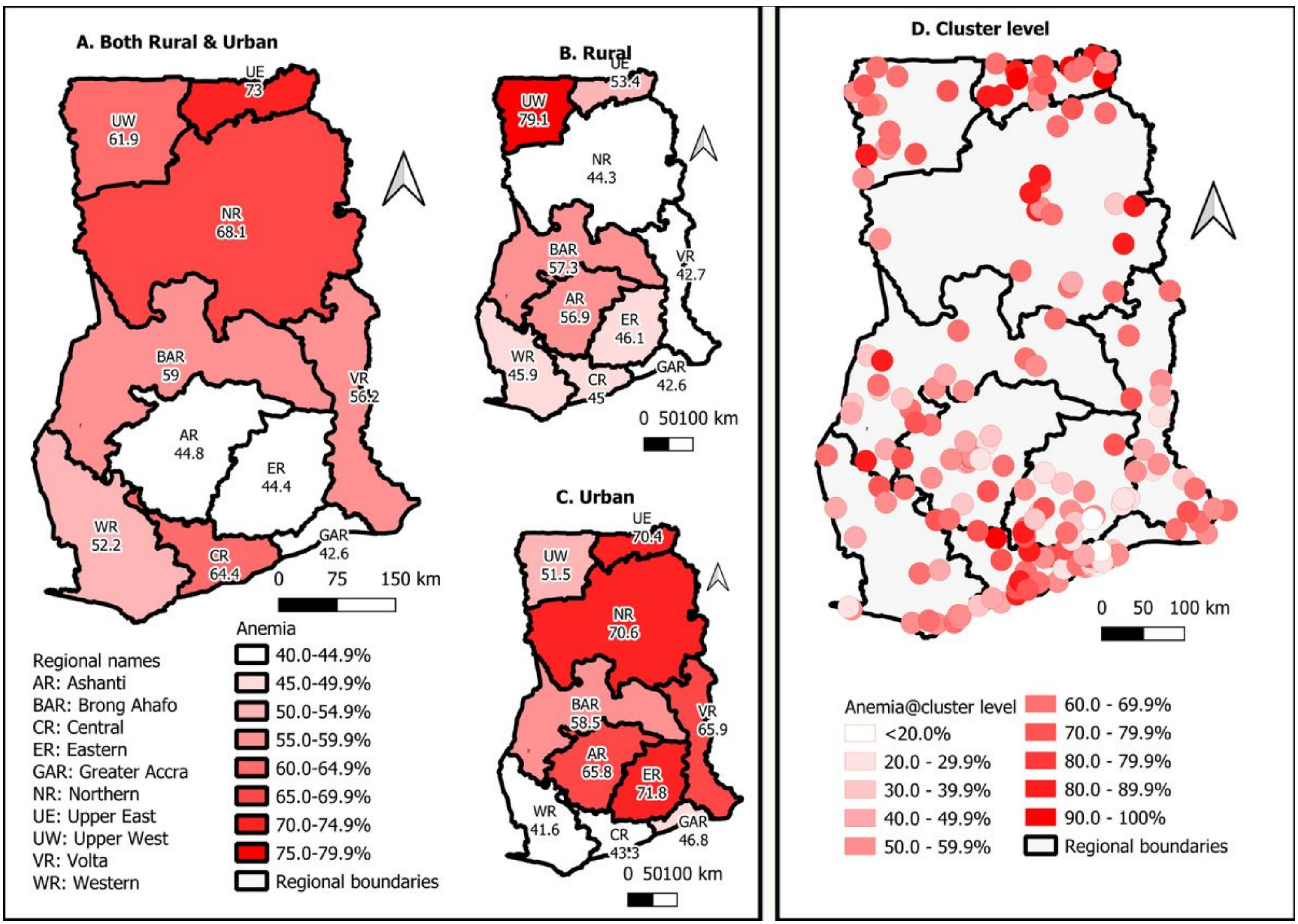

Figure 1

Prevalence of anemia at the regional (A), rural (B), urban (C) and cluster (D) levels in Ghana

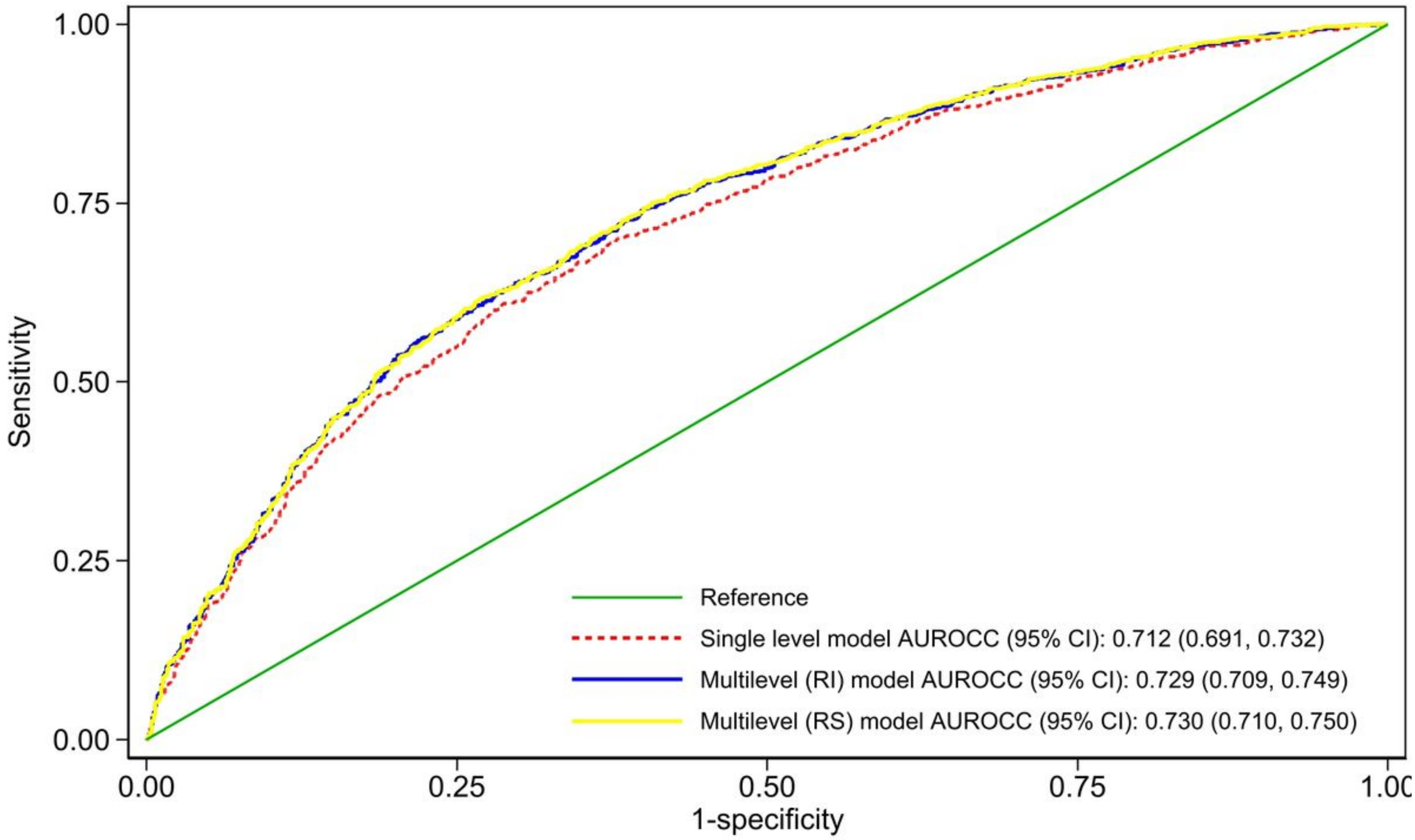

Figure 2

Comparison of the Area under the receiver operating characteristics curve (AUROCC) of the fixed and multilevel effect models for predicting under-five anemia.