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Household cooking fuel type and child anaemia in Sub-Saharan Africa: analysis of cross-sectional surveys of 95,056 children from 29 countries

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Household cooking fuel type and child anaemia in Sub-Saharan Africa: analysis of cross-sectional surveys of 95,056 children from 29 countries

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Abstract

Objective:

This study sought to investigate the association between household cooking fuel type, and the joint impact of household cooking fuel type and urbanicity on anaemia among children under the age of 5 in sub-Saharan Africa.

Design: We analysed cross-sectional data of 95,056 children under the age of 5 from 29 sub-Saharan African countries. Bivariate and multivariate analyses were performed using a chi-square test of independence and negative log-log regression respectively at $p<0.05$.

Outcome measures: Anaemia

Results: The percentage of children who had anaemia was 43%. Children from rural households that depend on unclean cooking fuels were more likely to be anaemic [AOR=1.028; 95% CI=1.011-1.046] compared to children from urban households using unclean cooking fuel. We also found that children in female-headed households [AOR=1.023; CI=1.007-1.039], children in large households [AOR=1.030; CI=1.008-1.052]; those in households with an improved source of drinking water [AOR=1.025; CI=1.009-1.041] had higher odds of suffering from anaemia. However, children with normal birth weight [AOR=0.969; CI=0.953-0.986], children aged 4 [AOR=0.935; CI=0.916-0.955], children whose mothers are aged 45-49 [AOR=0.913; CI=0.863-0.963] and those aged 30-34 [AOR=0.917; CI=0.887-0.948], children whose mothers had tertiary level of education [AOR=0.911; CI=0.872-0.953], children in rich households [AOR=0.963; CI=0.944-0.982] and those in households with improved type of toilet facility [AOR=0.975; CI=0.961-0.990] had lower odds of being anaemic.

Conclusions: Our study established an association between the joint effect of type of household cooking fuel and urbanicity and anaemia among children under the age of 5 in SSA. Childs' birth weight, current age, maternal age, sex of household head, age of household head, maternal education, wealth status, size of household, type of source of drinking water and country of residence are associated with childhood anaemia. It is therefore critical to promote the usage of clean cooking fuels among households and women in rural areas.

Keywords: Anaemia; Under-five Children; Sub-Saharan Africa; DHS; Public Health

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Strengths and limitations

- The major strength of this study is the use of recent nationally representative surveys, with relatively large sample sizes. This makes the findings generalisable to all under-five children in the countries we included in our study.

- Also, we employed rigorous statistical modelling to assess the association between the type of cooking fuel and anaemia while controlling for theoretical and practical confounders.

- The study, however, is limited by the cross-sectional nature of the design employed for the data collection. Due to this, it is impossible to detect temporality of sequence. Also, geographic region and Urbanicity Wealth were associated with child anaemia ($p<0.05$) but could not be included in the model due to multicollinearity.

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INTRODUCTION

In low and middle-income countries, anaemia remains a major public health problem which causes childhood mortality and morbidity [1]. Anaemia is a condition in which the haemoglobin level is lower than the body's required amount for physiological activities [2]. According to [3] about 273.2 million children suffer from anaemia globally with a general prevalence of 42.6%. However, its effects are disproportionate across regions, with sub-Saharan Africa (SSA) being one of the most affected with a startling prevalence rate of 62.3% [4].

Anaemia is a major contributor to some of the serious adverse health conditions in children and affects their cognitive, behavioural and physical development [3, 5—7]. The notable causes of anaemia in children are multifactorial and include deficiency of iron, and other micronutrients such as folate, vitamin B12 and vitamin A; malaria, HIV and chronic disease such as sickle cell disease [8].

Apart from these causes, a major environmental cause of anaemia is indoor air pollution as a result of biomass fuel use in cooking in households [9]. Household biomass fuel is a global air pollution issue that harms human health, the climate and the environment. About three billion people use biomass fuels such as plant residues, animal dung, wood and charcoal for daily domestic use [10]. Inefficient combustion of these fuels could release harmful gases such as sulphur dioxide (SO2), carbon monoxide (CO) and nitrogen dioxide (NO2), and Particulate Matter (PM) [11, 12]. According to [13], households that use biomass fuels are often exposed to peak indoor particulate matter (PM_{10}) levels greater than the air quality guidelines. The mechanism by which biomass fuels use could contribute to childhood anaemia are unknown. However, studies have shown that biomass fuel expels high carbon monoxide levels which bind with haemoglobin, form carboxyhaemoglobin and reduce the level of haemoglobin in the blood, which leads to anaemia. For instance, studies in India [9] and Swaziland [11] found the prevalence of anaemia to be significantly high among children in households that rely on biomass fuels for cooking.

Apart from anaemia, evidence of other adverse health outcomes spanning respiratory illnesses, cancer and eye problems from indoor air pollution due to inefficient burning of biomass fuels for cooking in poorly ventilated settings exist [14–16]. A majority of the burden is suffered by women who by custom are responsible for cooking and other household chores, and their children, especially, those below the age of 5 [16, 17]. The prevalence of the burden is relatively low in urban areas where clean fuels like liquid petroleum gas or natural gas and electricity are typically used. However, most rural residents mainly depend on biomass fuels [19]. These fuels include among others wood, animal dung, twigs and dry leaves, and crop residues such as straw and rice husks [20]. The high burden of adverse health outcomes among rural residents is that most of them often depends on unclean cooking fuels [15, 21, 22].

The associations between household biomass fuel use in cooking and important health variables of women and children such as adverse pregnancy outcomes (low birth weight, stillbirth) [14, 23] women health (BMI, anaemia) [14, 24] and the health of children under 5years of age (child weight, child anaemia) [16, 23] have been explored. Few studies have explored the association

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between household biomass fuel use, a notable source of indoor air pollution in LMICs with child anaemia in SSA. Further, critical to our understanding but absent in such sub-regional analysis by studies is the joint impact of household biomass fuel use and urbanicity on child anaemia in SSA. This study, therefore, seeks to investigate the joint effect of household biomass fuel use for cooking and urbanicity on anaemia among children under the age of 5 in SSA.

METHODS

Data and sampling

Nationally representative data from the Demographic and Health Surveys (DHS) Program for SSA countries from 2010 to 2018 were acquired for analysis in this study. The DHS program provides large secondary data gathered from surveys using probability sampling methods, following standard protocols that are internationally accepted. Different sets of questionnaires designed and pre-tested to ensure reliability and amenability for comparison of data gathered on various spatial and temporal scales are used in the survey. Some questionnaires the program uses include the "Children's questionnaire" "Mother's questionnaire", "Men's questionnaire" and "Household questionnaire". These questionnaires cover a broad range of variables cutting across demographics and anthropometrics, water and sanitation, health, wealth, nutrition among others. The program recruits and trains field officers to collect accurate data and measurement of weight, height, anaemia using recommended guidelines and instruments. Data on other important variables such as household cooking fuel, urbanicity, wealth, water and sanitation are taken at the household level. The dataset used in this study are: Children's Data - Children's Recode, and Household Data - Household Recode (variable names: caseid; v000; v001 v007; v013; v102; v113; v116; v136; v149; v151; v152; v190; bord; b4; b8; m19; hw2; v457; v005; hhid; hv001, hv000; hv226).

Study Countries

A sample of 95,056 was drawn from 29 countries (Figure 1) in SSA. For a country to be selected, it must meet the following criteria: should be found in SSA based on the United Nations regional groupings; it must have a DHS dataset with standardized questions and observations on anaemia level of children under five years as well as household cooking fuel type, urbanicity, source of drinking water and type of toilet facility. Where multiple datasets exist for a country, the most recent dataset is used. Detailed information on countries, together with years of survey are shown in Table 1.

Figure 1

Table 1

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Definition of important variables

The dataset provided information on household cooking fuel type, source of drinking water and toilet facility type at the household level. The observations for household cooking fuel were classified into "Clean" and "Unclean" (polluting fuels) following the criterion some studies [25, 26] used (see Table 2). The weight of the child at birth named as "Birth weight" was categorized as "Underweight" (<2.5kg) and "Normal" (≥2.5kg) (see, [27]). Also, the observations for the household source of drinking water and type of toilet facility were classified into “improved” and “unimproved” using the revised definitions by the WHO/UNICEF Joint Monitoring Programme (JMP) report [28]. Table 2 summarises the descriptions of improved and unimproved sources of water and toilet facilities (see [29]) for explication of the categorisation of these critical basic services.

Table 2

Measures

Outcome variable

Anaemia status of children is the outcome variable considered in this study. According to DHS, the anaemia status of living children within the age bracket 0-4 years before the survey night was taken. It has its responses classified into four (4) categories according to the WHO recommendation as (i) "Not anaemic" for children with haemoglobin count(g/dl) measuring above 11g/dl; (ii) "Mild anaemia" for haemoglobin count of 10-10.9g/dl; (iii) "Moderate anaemia" for haemoglobin count between 7.0-9.9g/dl; and (iv) "Severe anaemia" for haemoglobin count less than 7.0g/dl. Children with no observations for anaemia count (not tested) and those whose mothers were not listed in the household questionnaire were excluded. Observations under mild, moderate and severe were combined and recoded as "Anaemic (Yes)" and observations under not anaemic was recoded as "Not anaemic (No)". The Anaemia status of children was represented as a dichotomous variable with "0" representing "No" and 1 representing "Yes".

Main predictor variable

The predictor chosen for this study is a composite variable formed from the interactive effect of household cooking fuel type and urbanicity. The selection of the predictor variable was based on parsimony, literature review, theoretical relevance as well as practical significance. Household cooking fuel type and Urbanicity both had two categories since the former was classified into "Clean" and "Unclean" and the latter measured as "Rural" and "Urban" per the Demographic Health Survey (DHS). This, therefore, gave a four mutually exclusive groups: Unclean urban (households relying on "unclean" cooking fuel and found in urban areas); Unclean rural (households relying on "unclean" cooking fuel and found in rural areas); Clean urban (households using "clean" cooking fuels and found in urban areas); and clean rural (households using "clean"

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cooking fuels and found in rural areas). The rationale for the four-responses was based on previous studies [30,31]. Out of the four responses, "Unclean Urban" was chosen as the reference category in the models. The choice of the reference category was based guided by previous studies [32,33]. These authors explained that urban areas are considered as places with relatively higher levels of air pollution and its associated negative health outcomes, which has the potential of multiplied burden relative to child anaemia when households use unclean cooking fuels. This makes it prudent to use "Unclean Urban" as the reference category.

Compositional and contextual variables

Variables which relate to an individual's socio-demographic characteristics (biosocial and socio-cultural factors) together constitute compositional factors [34, 35]. Biosocial factors refer to underlying biological and physical attributes present in an individual at birth and are not amenable to change. Socio-cultural factors, on the other hand, refers to customs, beliefs, lifestyles and values [29].

Biosocial variables considered in this study included: sex of child (male, female); current age of the child in years with categories 0, 1, 2, 3, and 4; the age of mother (15-19, 20-24, 25-29, 30-34, 35-39,40-44, 45-49); sex of household head (male, female); the age of household head ("young adult" for those below 35years, middle-age adult for 35-55 years, and "old-age adult" for those above 55 years).

The study considered socio-cultural factors including educational attainment of the mother (no education, primary, secondary, tertiary); birth order number (1, 2, 3, 4, 5 and above); household size (small: 1-5, medium: 6-10, large: above 10). Also, the DHS collects data on the wealth index of all interviewed households and place them into five wealth quintiles (poorer, poor, middle, rich, richer). Observations of wealth index under poorer and poor were combined and recoded as "poor". Similarly, observations under "rich" and "richer" were combined and recoded as "rich". Finally, household source of drinking water and type toilet facility which were both categorized into "improved" and "unimproved".

According to studies [34, 36], contextual factors refer to those factors related to respondent's neighbourhood attributes or opportunities and services that are space-bound [29, 35, 36]. Contextual factors considered in this study include country and geographic region (Western Africa, Eastern Africa, Southern Africa, and Central Africa).

Data Analysis

The STATA version 14.0 MP software was used for the analysis of data. To understand the distribution of childhood anaemia and influence of predictive factors on anaemia, descriptive analysis was performed. Using ArcGIS 10.6, the data was integrated with ESRI Shapefiles to construct a map of the study countries showing the distribution of child anaemia. We then determined the associations between the anaemia status of children under five and the relevant predictors using inferential statistics. These relationships were further examined using multivariate techniques while controlling for theoretically relevant compositional and contextual

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factors. Statistical significance of 0.05 and 95% confidence interval (CI) was used in analysis and results presented as contingency tables.

Univariate analysis

Pearson chi-square test of independence and Cramer's V statistic were applied in the univariate analysis of predictors of child under five anaemia. The strength of associations between anaemia status and the predictors was tested using Cramer's V statistics.

Multivariate regression

The outcome variable (anaemia status of children under age 5) had 57% of responses in the non-affirmative and 43% were affirmative. The relationship between anaemia status and the interactive effect of household cooking fuel and urbanicity was analysed using a negative log-log regression model. A negative log-log regression model is apt when the responses to a dichotomous response variable are asymmetric in the [0, 1] interval for which the non-affirmative is more than 55% as in the case of the response variable in this study [37—39]. The likelihood of a child been anaemic was estimated and reported as exponential coefficients - odds ratios (OR). An OR of 1 means that the predictor does not affect the odds of a child been anaemic; OR >1 means that the predictor is associated with higher odds of been anaemic; and OR <1 means that the predictor is associated with lower odds of been anaemic. Clustering of observations in units of households was controlled by imposing on the models a "cluster" variable, thus, the identification numbers of the respondents at the cluster level. Missing responses for the outcome and main predictor variables were dropped. This adjusted the SE leading to statistically robust estimation of parameters.

At the multivariate level, we first performed multicollinearity diagnosis (see Supplementary file 1) of the variables considered be fitting the regression models. Four (4) models were run: the joint effect of household cooking fuel type and urbanicity (Model 1); birth weight and biosocial factors (Model 2), sociocultural (Model 3), and the contextual (Model 4). Literature and parsimony informed the chosen groups of references for the predictor variables in the models. Respondents from urban settings who rely on unclean cooking fuel types "Unclean urban" was chosen for the key predictor. This is selected considering the fact that urban residents are commonly exposed to relatively high levels of air pollutants and households using unclean cooking fuels could potentially suffer multiplied effects including the risk of high child under age five years anaemia prevalence. The selected reference group for sex of child and sex of household head was "male". Studies show that males in households are often less worried about children under five years as well as water and sanitation issues [29, 40]. The selected reference group for the current age of the child was "0". Young adults and no education were respectively selected as reference groups for the age of household head and educational attainment of the mother. Unimproved was selected as the reference group for the source of drinking water and type of toilet facility. The young adult group was selected as the reference group because this is a demographic group in transition and may be unable to provide better services for the family while those with no education has a direct effect on the ability to afford and capacity to

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spearhead decision-making of households for better services and conditions. Small household size was selected as the reference group for household size.

Ethical considerations

We used datasets provided by the Demographic Health Surveys Program and have not had any form of contact with the study participants. The program obtains approval from the Ethics Boards of the various partner organisations and countries such as the Ministries of Health. The DHS Program recognizes and adheres to established international and local ethical standards and protocols in its surveys. The ICF International's Institutional Review Board (IRB) through The DHS Program's reviewed and approved all survey procedures and instruments used before implementation. The board aside providing technical assistance to the program ensures that the survey complies with the United States Department of Health and Human Services regulations for the protection of human subjects CFR 46 as well as the laws of the individual countries. Further information regarding the DHS data usage and ethical standards can be accessed at https://dhsprogram.com/data/Access-Instructions.cfm.

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research.

RESULTS

Descriptive analysis

The study included 95,056 children under the age of 5 years from 29 SSA countries. The percentage of children who suffered anaemia was 57% while those who were not anaemic accounted for 43%. A majority (57%) of the children included in the survey were in rural households that used unclean cooking fuels. The results indicate that only 13% of children under the age of 5years are from households that rely on clean cooking fuel whiles 87% lived in households using unclean cooking fuels. Further, the prevalence of anaemia was highest (59%) among children in urban households that use unclean cooking fuels, and rural households that use cleaning cooking fuels. Even though a majority of children were in households with an improved source of drinking water (75%); and improved toilet facility (54%), most of these children, 58% and 60% respectively suffered anaemia. Child anaemia is high (60%) among children in rich households, which constitute a slightly higher percentage (41%) of households by wealth status. Even though a relatively high percentage (35%) of children included in the study were in rural households of poor wealth status, a majority (59%) of children from rich households in rural areas were anaemic. On educational attainment of mothers, only a few children (4%) belonged to mothers who had tertiary education, most (65%) of whom were anaemic. Notwithstanding the relatively few children from Namibia (1%) and Rwanda (4%) included in the survey, each recorded 82% child anaemia. Despite accounting for only 4% of the children studied, Benin recorded the least (31%) prevalence of child anaemia. Categorizing the countries into their geographical location, we found that, of the 17% and 18% of children from Southern Africa and Central Africa, 74% of children each region suffered anaemia.

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The probability (P) value of all variables except the sex of the child was significant. The Pearson Chi-squared analysis, therefore, rejects the null hypotheses that anaemia level is independent of the source of drinking water and toilet facility as well as compositional and contextual factors. These results, therefore, signify that household source of drinking water and type of toilet facility affect anaemia level of children under five years old. Again, the P-values show that the figures obtained for anaemia level were not by chance and if the analyses were repeatedly run, the same results would be obtained. Cramer's v statistics however shows weak to moderate associations between the key predictor, compositional and contextual factors. Contingency Table 3 shows the detailed results.

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Table 3

Multivariate analysis

Table 4 shows the results from the negative log-log regression analysis on the relationship between the type of household cooking fuel and anaemia among children under five in SSA. In Model 4, the final model that controlled for all the variables including country, it was found that children from rural households that depend on unclean cooking fuels were more likely to be anaemic [AOR=1.028; 95% CI=1.011-1.046] as compared to children from urban households using unclean cooking fuel. With birthweight, it was found from our study that children with normal weight had lower odds [AOR=0.969; CI=0.953-0.986] of being anaemic compared to underweight children. The odds of suffering from anaemia decreased with the age of the child. It was found that children aged 4 had the lowest odds [AOR=0.935; CI=0.916-0.955] of suffering from anaemia compared with those less than 1 year (0). With maternal age, compared with those age 15-19, all the age categories showed statistically significant association with anaemia. However, children whose mother are aged 45-49 [AOR=0.913; CI=0.863-0.963] and those aged 30-34 [AOR=0.917; CI=0.887-0.948] had the lowest odds of being anaemic. We also found that children in female-headed households [AOR=1.023; CI=1.007-1.039]; middle-aged adults [AOR=1.026; CI=1.009-1.043], old age adults [AOR=1.043; CI=1.021-1.065] were more likely to be anaemic compared with those in male-headed households; and households headed by young adults. With regards to the educational attainment of child's mother, children whose mother's highest educational attainment is the tertiary level had the lowest odds [AOR=0.911; CI=0.872-0.953] of suffering from anaemia compared with those whose mothers had no formal education.

The result shows that children in large households [AOR=1.033; CI=1.008-1.052]; those in households with the improved source of drinking water [AOR=1.025; CI=1.009-1.041] had higher odds of being suffering from anaemia compared to those in small household and those whose source of drinking is unimproved respectively. Children in rich households [AOR=0.963; CI=0.944-0.982]; those in the household with an improved type of toilet facility [AOR=0.975; CI=0.961-0.990] had lower odds of being anaemic compared with those in poor households, and households with unimproved toilet facility respectively. With country, apart from Benin, all the

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children in the other countries had lower odds of being anaemic with those in Namibia having the lowest odds [AOR=0.390; CI=0.353-0.430] compared to children in Angola (see Table 4).

Table 4

DISCUSSION

In this current study, our principal aim was to investigate the association between household biomass fuel use, and the joint effect of household biomass fuel use for cooking and urbanicity on anaemia among children under the age of 5 in SSA. The study showed that children from rural households that depend on unclean cooking fuels were more likely to be anaemic compared with children from urban households using unclean cooking fuel. This is in line with previous studies in various parts of the world such as Timor-Lest [21] and India [15, 22]. Although this study was a cross-sectional study and could not claim causality, some studies [15] have explained that exposure to unclean cooking fuels may lead to systemic inflammation which is regarded as a popular cause of anaemia, mediated by inflammatory cytokines such as tumour necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), interleukin-6 (IL-6), and interferon-γ (IFN-γ) [37]. The pathways by which these causes anaemia include dysregulation of iron homeostasis, impaired erythropoietin response to reduced haemoglobin levels, and impaired marrow response to erythropoietin [15, 41]. Apart from the key independent variable, we controlled for other key factors associated with anaemia among children under five which are worth discussing in light of previous evidence.

We found that the birth weight of the child had a statistically significant association with anaemia. Specifically, children with normal weight had lower odds of being anaemic compared with underweight children. This aligns with previous studies in Ethiopia [42] and Brazil [43]. Some previous studies espoused that there is a direct link between food consumption and anaemia. Due to this, in a household where there is no food security, it can affect the nutritional status of children, which could contribute to anaemia [44, 45]. Relatedly, we found that children in large households had higher odds of suffering from anaemia compared to those in a small household. This finding confirms a previous study in Ethiopia [46]. Insufficient consumption of appropriate quantity of nutrients due to the high numbers in the households could possibly account for this observation as explained by [46].

The study also established that the socio-economic status (education and wealth) of women had a statistically significant association with child anaemia. Specifically, it was found that children whose mothers are in the rich wealth status, as well as those with tertiary level of education, have lower odds of being anaemic. This corroborates several previous studies in SSA and other countries such as Ethiopia [42, 47, 48], Brazil [49], Switzerland [50], Burma [51], and India [52]. There are three pathways to the explanation of this finding. First, on the supply side, children from households with high-socio economic status can buy nutritious foods for their children,

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unlike the poor ones who might not be able to afford three square meals a day. In other words, the poor might lack the resources to purchase nutritious foods for their children. Second, evidence also suggests that mothers in poor households are also anaemic and the probability of their children also being anaemic is high. Thirdly, in terms of education, mothers who are highly educated can translate the health education they receive during child welfare clinics into practice. Besides, those who are highly educated can recognise danger signs related to childhood illnesses that warrant emergency care [46, 53].

Another major finding in our study was that the odds of suffering from anaemia decreased with the age of the child. This finding is supported by other studies conducted in Ethiopia [54, 42, 44, 55] Ghana [56], and Uganda [57]. The possible reason for this association is that in most cases as the children grow, they can eat varied foods which might be sufficient in iron and as a result could prevent the occurrence of anaemia [46]. We also observed a statistically significant association between maternal age and child's anaemia. Specifically, children whose mothers are aged 45-49 and those aged 30-34 had the lowest odds of being anaemic. This is consistent with previous studies in Ethiopia [46]. It is possible that as mothers advance in age, they gain experiences with childcare and also, they are more likely to be exposed to education on appropriate practices on childhood nutrition compared with those who are adolescents. In line with a previous study [58], we also found that children in female-headed households, middle-aged adults, old age adults were more likely to be anaemic compared with those in male-headed households; and households headed by young adults. Surprisingly, our study showed that children in households with an improved source of drinking water had higher odds of being anaemic. This is contrary to other empirical studies in Bangladesh [55], India [22], Benin and Mali [59]. Longitudinal case-control studies coupled with qualitative evidence are needed to unravel this counter-intuitive finding.

CONCLUSION

Our study found that there is an association between the joint effect of household biomass fuel use for cooking and urbanicity and anaemia among children under the age of 5 in SSA. Apart from this we also found that birth weight of the child, age of the child, maternal age, sex of household head, age of household head, maternal education, wealth status, size of household, type of source of drinking water and country of residence are associated with childhood anaemia. The following recommendations are therefore made for policy and practice. Firstly, it is critical to promote clean fuel usage among households and women in rural areas. This could be done by governments in various countries by enhancing access and subsidising the cost of natural and or, liquified petroleum gas [LPG] and cylinders. Second, it is also imperative to advocate for improvement in female education which could lead to an improvement in the socio-economic status of the women. Thirdly, maternal education by community health nurses on the risk factors of anaemia is also strongly suggested. Stakeholders that seek to improve maternal and child health should also consider these associated factors.

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Abbreviations
CI: Confidence interval
DHS: Demographic health survey
SSA: sub-Saharan Africa
PM: Particulate Matter
WHO: World Health Organization

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IA contributed to the study design and conceptualization. IA and AA performed the analysis. IA, AS, AA, BOA and SY drafted the initial draft. AS, AA, BOA and SY provided technical support and critically reviewed the manuscript for its intellectual content. SY had final responsibility to submit for publication. All authors read and amended drafts of the paper and approved the final version.

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Data for this study were sourced from Demographic and Health surveys (DHS) and available here: http://dhsprogram.com/data/available-datasets.cfm.

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Supplementary material
Supplementary file 1. Multicollinearity diagnosis

Figure Legends
Figure 1. Map of study countries showing the distribution of child under age five years anaemia status

Table 1. Selected countries and available dataset

Country	Year(n)	Country	Year(n)
Angola	2016 (5,390)	Malawi	2016 (4,769)
Benin	2018 (3,430)	Mali	2018 (1,659)
Burkina Faso	2010 (6,674)	Mozambique	2015 (3,824)
Burundi	2017 (6,519)	Namibia	2013 (1,913)
Cameroon	2019 (3,135)	Niger	2012 (1,325)
Congo	2012 (3,309)	Nigeria	2018 (3,392)
Cote D'Ivoire	2012 (2,082)	Rwanda	2015 (3,476)
DR Congo	2014 (3,849)	Sierra Leone	2013 (2,398)
Ethiopia	2016 (1,896)	Senegal	2017 (2,881)
Gabon	2012 (3,185)	Tanzania	2016 (5,812)
Gambia	2013 (1,556)	Togo	2014 (1,948)
Ghana	2014 (1,578)	Uganda	2016 (3,168)
Guinea	2018 (1,773)	Zambia	2019 (7,384)
Lesotho	2014 (1,235)	Zimbabwe	2015 (4,737)
South Africa	2016 (1,084)		

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Table 2. Classification of the source of drinking water and toilet facilities under the WHO/UNICEF Joint Monitoring Programme and cooking fuel.

Service	Improved/Clean	Unimproved/Unclean
Drinking water sources	Piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water.	Unprotected dug well, unprotected spring, river, dam, lake, pond, stream, canal and irrigation canal
Type of toilet facilities	Flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slabs.	Pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation.
Cooking fuel type	Electricity, liquid petroleum gas (LPG), natural gas and biogas	Kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass and animal dung

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Table 3. Percentage distribution of Anaemia level by predictor variables.

Variable χ2(df) (p-value; Cramer's V)	Weighted n	Weighted %	Anaemia status Yes (%)	No (%)
Household cooking fuel χ2=0.2206 (1); (p=0.639; Cramér's V = 0.0015)				
Unclean	83,077	87	57	43
Clean	11,978	13	57	43
Household cooking fuel Urbanicity χ2=38.3022 (3); (p<0.001; Cramér's V =0.0200)				
Unclean Urban	29,148	31	59	41
Unclean Rural	53,930	57	56	44
Clean Urban	6,055	6	56	44
Clean Rural	5,923	6	59	42
Drinking water source χ2=80.0251 (1); (p<0.001; Cramér's V = -0.0290)				
Unimproved	23,298	25	54	46
Improved	71,758	75	58	42
Type of toilet facility χ2=357.2000 (1); (p<0.001; Cramér's V = -0.0612)				
Unimproved	43,618	46	54	46
Improved	51,438	54	60	40
Wealth status χ2= 281.9885(2); (p<0.001; Cramér's V =0.0544)				
Poor	37,185	39	55	45
Middle	18,619	20	54	46
Rich	39,251	41	60	40
Sex of child χ2= 3.5696(1); (p=0.059; Cramér's V =-0.0061)				
Male	47,997	50	57	43
Female	47,058	50	57	43
Birth weight χ2=17.9842(1); (p<0.001; Cramér's V = -0.0140)				
Under weight	13,571	15	56	44
Normal	77,283	85	58	42
Current age of child χ2= 58.1591(4); (p<0.001; Cramér's V = 0.0252)				
0	17,418	19	56	44
1	20,043	22	55	45
2	18,454	20	57	43
3	18,205	20	58	42
4	16,878	19	59	41
Age of mother(years) χ2= 111.3956(6); (p<0.001; Cramér's V = 0.0342)				
15-19	1,415	7	56	44
20-24	4,784	22	59	41
25-29	5,830	27	57	43
30-34	4,745	22	55	45
35-39	3,246	15	54	46
40-44	1,328	6	57	43

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45-49	342	2	56	44
Urbanicity Wealth χ2= 395.6355(5); (p<0.001; Cramér's V = 0.0644)				
Urban Poor	4,187	4	50	50
Urban Middle	4,735	5	50	50
Urban Rich	26,281	28	61	39
Rural Poor	32,998	35	55	45
Rural Middle	13,884	15	56	44
Rural Rich	12,970	14	59	41
Birth order number χ2= 128.4928(4); (p<0.001; Cramér's V =0.0367)				
1	23,293	25	59	41
2	19,367	20	58	42
3	15,437	16	58	42
4	11,803	12	56	44
5 and above	25,155	26	54	46
Age of household head χ2= 116.8819(2); (p<0.001; Cramér's V = 0.0350)				
Young adult	37,260	39	59	41
Middle-aged adult	44,680	47	56	44
Older adults	13,115	14	54	46
Mother's highest level of education χ2= 1.1e+03(3); (p<0.001; Cramér's V = 0.1056)				
No formal education	28,082	30	49	51
Primary	35,506	37	59	41
Secondary	27,968	29	61	39
Tertiary	3,499	4	65	35
Household size χ2= 306.2649(2); (p<0.001; Cramér's V = 0.0567)				
Small	41,898	44	59	41
Medium	41,620	44	57	43
Large	11,538	12	50	50
Country χ2= 7.3e+03 (28); (p<0.001; Cramér's V =0.2773)				
Angola	5,038	5	37	63
Benin	3,533	4	31	69
Burkina Faso	7,030	7	52	48
Burundi	6,722	7	58	42
Cameroon	3,345	4	61	39
Congo	1,653	2	48	52
Cote D'Ivoire	1,906	2	45	55
DR Congo	3,737	4	58	42
Ethiopia	1,919	2	75	25
Gabon	2,858	3	43	57
Gambia	1,707	2	39	61
Ghana	1,412	1	58	42
Guinea	1,675	2	56	44
Lesotho	1,202	1	72	28

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Malawi	4,773	5	69	31
Mali	2,136	2	44	56
Mozambique	4,102	4	39	61
Namibia	1,831	2	82	18
Niger	1,428	2	59	41
Nigeria	2,758	3	46	54
Rwanda	3,547	4	82	18
Sierra Leone	2,425	3	55	45
Senegal	2,484	3	49	51
Tanzania	7,430	8	54	46
Togo	1,853	2	56	44
Uganda	3,415	4	69	31
Zambia	7,174	8	73	27
Zimbabwe	4,891	5	75	25
South Africa	1,069	1	72	28
Geographic region χ2= 3.9e+03 (3); (p<0.001; Cramér's V =0.2019)				
Western Africa	30,348	32	48	52
Eastern Africa	31,909	34	61	39
Southern Africa	16,167	17	74	26
Central Africa	16,632	18	74	26

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Table 4. Negative log-log regression model showing the relationship between Anaemia status and predictor variables

Variables	Key Predictor Model 1 OR	Robust SE	P value	Conf. Interval		Key Predictor + Biosocial factors Model 2 AOR	Robust SE	P value	Conf. Interval		Socio-cultural factors Model 3 AOR	Robust SE	P value	Conf. Interval		Contextual factors Model 4 AOR	Robust SE	P value	Conf. Interval	
Household cooking fuel Urbanicity (ref: Unclean Urban)																				
Unclean Rural	1.040	0.007	**<0.001**	1.026	1.055	1.027	0.008	**<0.001**	1.012	1.042	0.940	0.008	**<0.001**	0.924	0.956	1.028	0.009	**0.001**	1.011	1.046
Clean Urban	1.037	0.015	**0.015**	1.007	1.067	1.043	0.016	**0.006**	1.012	1.074	1.043	0.016	**0.005**	1.013	1.074	1.004	0.015	0.785	0.975	1.034
Clean Rural	1.001	0.015	0.972	0.972	1.030	0.997	0.016	0.832	0.966	1.028	0.928	0.015	**<0.001**	0.899	0.958	1.003	0.016	0.847	0.973	1.034
Birth weight (ref: Underweight)																				
Normal						0.967	0.009	**<0.001**	0.950	0.984	0.973	0.009	**0.002**	0.956	0.990	0.969	0.008	**<0.001**	0.953	0.986
Sex (ref: Male)																				
Female						0.992	0.007	0.225	0.979	1.005	0.992	0.007	0.228	0.979	1.005	0.996	0.006	0.525	0.984	1.008
Current age of child (ref: 0)																				
1						1.003	0.010	0.803	0.983	1.023	0.998	0.010	0.809	0.978	1.017	0.969	0.009	**0.001**	0.951	0.987
2						0.984	0.010	0.121	0.964	1.004	0.983	0.010	0.074	0.963	1.003	0.957	0.009	**<0.001**	0.939	0.976
3						0.974	0.011	**0.015**	0.953	0.995	0.974	0.010	**0.015**	0.954	0.995	0.949	0.010	**<0.001**	0.930	0.968
4						0.956	0.011	**<0.001**	0.936	0.978	0.961	0.011	**<0.001**	0.940	0.983	0.935	0.010	**<0.001**	0.916	0.955
Age of mother (ref: 15-19)																				
20-24						0.948	0.014	**<0.001**	0.921	0.976	0.935	0.014	**<0.001**	0.908	0.963	0.957	0.013	**0.002**	0.932	0.983
25-29						0.943	0.014	**<0.001**	0.917	0.970	0.900	0.015	**<0.001**	0.871	0.929	0.937	0.014	**<0.001**	0.909	0.966
30-34						0.919	0.014	**<0.001**	0.892	0.947	0.857	0.016	**<0.001**	0.827	0.889	0.917	0.016	**<0.001**	0.887	0.948
35-39						0.943	0.015	**<0.001**	0.914	0.972	0.871	0.017	**<0.001**	0.837	0.905	0.935	0.018	**<0.001**	0.901	0.970
40-44						0.943	0.017	**0.001**	0.910	0.978	0.855	0.019	**<0.001**	0.818	0.893	0.925	0.020	**<0.001**	0.887	0.964
45-49						0.957	0.025	0.100	0.909	1.008	0.846	0.025	**<0.001**	0.798	0.896	0.913	0.026	**0.001**	0.863	0.96305
Sex of household head (ref: Male)																				
Female						0.983	0.008	**0.039**	0.967	0.999	1.003	0.008	0.675	0.987	1.020	1.023	0.008	**0.004**	1.007	1.039
Age of household head (ref: Young adults)																				
Middle-aged adults						1.065	0.009	**<0.001**	1.048	1.082	1.039	0.009	**<0.001**	1.021	1.057	1.026	0.009	**0.002**	1.009	1.043

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Old-aged adults	1.111	0.011	**<0.001**	1.089	1.133	1.062	0.012	**<0.001**	1.039	1.086	1.043	0.011	**<0.001**	1.021	1.065
Educational attainment of mother (ref: No education)															
Primary						0.843	0.007	**<0.001**	0.830	0.857	0.950	0.008	**<0.001**	0.934	0.966
Secondary						0.835	0.008	**<0.001**	0.820	0.851	0.937	0.009	**<0.001**	0.919	0.956
Tertiary						0.820	0.018	**<0.001**	0.785	0.857	0.911	0.021	**<0.001**	0.872	0.953
Birth order number (ref: 1)															
2						1.035	0.011	**0.002**	1.013	1.058	1.016	0.011	0.128	0.995	1.037
3						1.042	0.013	**0.001**	1.016	1.069	1.009	0.012	0.463	0.985	1.033
4						1.068	0.016	**<0.001**	1.038	1.099	1.025	0.014	0.070	0.998	1.054
5 and above						1.074	0.016	**<0.001**	1.042	1.106	1.019	0.015	0.180	0.991	1.048
Household size (ref: Small)															
Medium						1.022	0.009	**0.010**	1.005	1.039	1.008	0.008	0.334	0.992	1.024
Large						1.096	0.012	**<0.001**	1.072	1.120	1.030	0.011	**0.007**	1.008	1.052
Wealth status (ref: Poor)															
Middle						1.028	0.009	**0.002**	1.010	1.046	1.018	0.009	**0.033**	1.002	1.036
Rich						0.951	0.009	**<0.001**	0.933	0.970	0.963	0.010	**<0.001**	0.944	0.982
Source of drinking water (ref: Unimproved)															
Improved						0.987	0.008	0.113	0.972	1.003	1.025	0.008	**0.002**	1.009	1.041
Type of toilet facility (ref: Unimproved)															
Improved						0.955	0.007	**<0.001**	0.941	0.970	0.975	0.007	**0.001**	0.961	0.990
Country (ref: Angola)															
Benin											1.033	0.013	**0.011**	1.008	1.059
Burkina Faso											0.798	0.012	**<0.001**	0.775	0.822
Burundi											0.752	0.012	**<0.001**	0.729	0.776
Cameroon											0.735	0.016	**<0.001**	0.705	0.767
Congo											0.879	0.016	**<0.001**	0.848	0.910
Cote D'Ivoire											0.880	0.018	**<0.001**	0.846	0.916
DR Congo											0.776	0.016	**<0.001**	0.746	0.808
Ethiopia											0.527	0.025	**<0.001**	0.479	0.579
Gabon											0.932	0.018	**<0.001**	0.897	0.968
Gambia											0.945	0.019	**0.005**	0.908	0.983

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Ghana	0.771	0.021	**<0.001**	0.731	0.812
Guinea	0.769	0.018	**<0.001**	0.735	0.805
Lesotho	0.574	0.027	**<0.001**	0.524	0.629
Malawi	0.616	0.015	**<0.001**	0.588	0.645
Mali	0.905	0.017	**<0.001**	0.873	0.938
Namibia	0.390	0.020	**<0.001**	0.353	0.430
Niger	0.736	0.023	**<0.001**	0.693	0.781
Nigeria	0.950	0.016	**0.002**	0.920	0.982
Rwanda	0.398	0.014	**<0.001**	0.372	0.425
Sierra Leone	0.779	0.017	**<0.001**	0.746	0.812
Senegal	0.834	0.015	**<0.001**	0.805	0.865
Tanzania	0.820	0.013	**<0.001**	0.795	0.845
Togo	0.791	0.018	**<0.001**	0.757	0.826
Uganda	0.612	0.016	**<0.001**	0.582	0.644
Zambia	0.550	0.011	**<0.001**	0.528	0.572
Zimbabwe	0.535	0.014	**<0.001**	0.509	0.562
South Africa	0.569	0.030	**<0.001**	0.514	0.630

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Table S1: STROBE 2007 (v4) Statement—Checklist of items that should be included in reports of *cross-sectional studies*

Section/Topic	Item #	Recommendation	Reported on page #
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	Page 1
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	Page 2
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Page 4-5
Objectives	3	State specific objectives, including any prespecified hypotheses	Page 5
Methods			
Study design	4	Present key elements of study design early in the paper	Page 5
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Page 5
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Page 5
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	Page 6
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	N/A
Bias	9	Describe any efforts to address potential sources of bias	Page 7-8
Study size	10	Explain how the study size was arrived at	Page 5
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	Page 6-7
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Page 7-8
		(*b*) Describe any methods used to examine subgroups and interaction	Page 7-8
		(*c*) Explain how missing data were addressed	Page 5

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		(*d*) If applicable, describe analytical methods taking account of sampling strategy	Page 5
		(*e*) Describe any sensitivity analyses	N/A
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	N/A
		(b) Give reasons for non-participation at each stage	N/A
		(c) Consider use of a flow diagram	N/A
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	9-10
		(b) Indicate number of participants with missing data for each variable of interest	N/A
Outcome data	15*	Report numbers of outcome events or summary measures	N/A
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Page 10-11
		(*b*) Report category boundaries when continuous variables were categorized	N/A
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	N/A
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	N/A
Discussion			
Key results	18	Summarise key results with reference to study objectives	Page 11-122
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and magnitude of any potential bias	Page 1
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	Page 1
Generalisability	21	Discuss the generalisability (external validity) of the study results	Page 1
Other information			

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Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	N/A

*Give information separately for cases and controls in case-control studies and, if applicable, for exposed and unexposed groups in cohort and cross-sectional studies.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Supplementary file 1. Multicollinearity diagnosis

Variable	**VIF(Mean=1.43)**	**Tolerance**	**R-Squared**
Anaemis Status	1.04	0.9658	0.0342
Cooking fuel Urbanicity	1.15	0.871	0.129
Birth weight	1.01	0.991	0.0089
Sex of child	1.00	0.997	0.0025
Current age of child	1.08	0.926	0.074
Age of mother	2.39	0.4181	0.5819
Sex of household head	1.03	0.9747	0.0253
Age of household head	1.35	0.742	0.258
Educational attainment of mother	1.30	0.7668	0.2332
Birth order number	2.52	0.3971	0.6029
Household size	1.40	0.713	0.2862
Wealth status	1.61	0.6196	0.3804
Urbanicity Wealth	1.40	1.18	0.2867
Source of drinking water	1.16	0.864	0.1354
Type of toilet facility	1.34	0.7467	0.2533
Country	1.11	0.8983	0.2533
Geographical region	1.35	0.7386	0.2614

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Household cooking fuel type and childhood anaemia in Sub-Saharan Africa: analysis of cross-sectional surveys of 123,186 children from 29 countries

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Household cooking fuel type and childhood anaemia in Sub-Saharan Africa: analysis of cross-sectional surveys of 123,186 children from 29 countries

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Abstract

Objective: This study sought to investigate the joint effect of household cooking fuel type and urbanicity (rural-urban residency) on anaemia among children under the age of 5 in sub-Saharan Africa.

Design: We analysed cross-sectional data of 123,186 children under the age of 5 from 29 sub-Saharan African countries gathered between 2010 and 2019 by the Demographic and Health Survey (DHS) Program. Bivariate (chi-square test of independence) and multilevel logistic regression were used to examine the effect of urbanicity-household cooking fuel type on child anaemia. Results were reported as adjusted odds ratios (aORs) with 95% confidence intervals (CIs) at $p<0.05$..

Outcome measures: Anaemia status

Results: The percentage of children who suffered anaemia was 64%. The percentage of children who suffered anaemia was high in children born to mothers in Western Africa (75%) and low among those born in Southern Africa (54%). Children from rural households that depend on unclean cooking fuels [aOR=1.120; 95% CI=1.033-1.214] and rural households that depend on clean cooking fuels [aOR=1.256; 95% CI=1.080-1.460] were more likely to be anaemic as compared to children from urban households using clean cooking fuel. Child age, sex of child, birth order, perceived birth size, age of mother, BMI of mother, education, marital status, employment status, antenatal care, wealth, household size, access to electricity, type of toilet facility, source of drinking water, and geographic region had significant associations with anaemia status.

Conclusions: Our study established an association between the joint effect of type of household cooking fuel and urbanicity and anaemia among children under the age of 5 in SSA. It is therefore critical to promote the usage of clean cooking fuels among households and women in rural areas. These should be done taking into consideration the significant child, maternal, household, and contextual factors identified in this study.

Keywords: Anaemia; Under-five Children; Sub-Saharan Africa; DHS; Public Health

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Strengths and limitations

- The major strength of this study is the use of recent nationally representative surveys, with relatively large sample sizes. This makes the findings generalisable to all under-five children in the countries we included in our study.
- Also, we employed rigorous statistical modelling to assess the association between the type of cooking fuel and anaemia while controlling for theoretical and practical confounders.
- The study, however, is limited by the cross-sectional nature of the design employed for the data collection. Due to this, it is impossible to detect temporality of sequence.
- Considering that several proximal, intermediate and distal factors could moderate the effects of household cooking fuel type and urbanicity on child anaemia, we acknowledge that those considered in this study are not exhaustive. Based on data availability, practical relevance and parsimony, the variables included in this study were chosen.

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INTRODUCTION

In low and middle-income countries, anaemia remains a major public health problem which causes childhood mortality and morbidity [1]. Anaemia is a condition in which the haemoglobin level is lower than the body's required amount for physiological activities [2]. According to [3] about 273.2 million children suffer from anaemia globally with a general prevalence of 42.6%. However, its effects are disproportionate across regions, with sub-Saharan Africa (SSA) being one of the most affected with a startling prevalence rate of 62.3% [4].

Anaemia is a major contributor to some of the serious adverse health conditions in children and affects their cognitive, behavioural and physical development [3,5–7]. The notable causes of anaemia in children are multifactorial and include deficiency of iron, and other micronutrients such as folate, vitamin B12 and vitamin A; malaria, HIV and chronic disease such as sickle cell disease [8].

Apart from these causes, a major environmental cause of anaemia is indoor air pollution as a result of biomass fuel use in cooking in households [9]. Household biomass fuel is a global air pollution issue that harms human health, the climate, and the environment. About three billion people use biomass fuels such as plant residues, animal dung, wood, and charcoal for daily domestic use [10]. Inefficient combustion of these fuels could release harmful gases such as sulfur dioxide (SO2), carbon monoxide (CO) and nitrogen dioxide (NO2), and Particulate Matter (PM) [11,12]. According to [13], households that use biomass fuels are often exposed to peak indoor particulate matter (PM_{10}) levels greater than the air quality guidelines. The mechanism by which biomass fuels use could contribute to childhood anaemia are unknown. But it has been postulated by Accinelli et al. [14] that biomass fuel exposure causes lung inflammation with elevated levels of IL-6, which produces in the liver hepcidin, a negative regulator of iron stores. However, studies have shown that biomass fuel expels high carbon monoxide levels which bind with haemoglobin, form carboxyhaemoglobin and reduce the level of haemoglobin in the blood, which could lead to functional anaemia, with an adequate Hb level. For instance, studies in India [9] and Swaziland [11] found the prevalence of anaemia to be significantly high among children in households that rely on biomass fuels for cooking.

Apart from anaemia, evidence of other adverse health outcomes spanning respiratory illnesses, cancer, and eye problems from indoor air pollution due to inefficient burning of biomass fuels for cooking in poorly ventilated settings exist [15–17]. A majority of the burden is suffered by women who by custom are responsible for cooking and other household chores, and their children, especially, those below the age of 5 [17,18]. The prevalence of the burden is relatively low in urban areas where clean fuels like liquid petroleum gas or natural gas and electricity are typically used. However, most rural residents mainly depend on biomass fuels [19]. These fuels include among others wood, animal dung, twigs, and dry leaves, and crop residues such as straw and rice husks [20]. The high burden of adverse health outcomes among rural residents is that most of them often depend on unclean cooking fuels [16,21,22].

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The associations between household biomass fuel use in cooking and important health variables of women and children such as adverse pregnancy outcomes (low birth weight, stillbirth) [15,23] women health (BMI, anaemia) [15,24], and the health of children under 5years ``of age (child weight, child anaemia) [16, 23] have been explored. Few studies have explored the association between household biomass fuel use, a notable source of indoor air pollution in LMICs with child anaemia in SSA. Further, critical to our understanding but absent in such sub-regional analysis by studies is the joint impact of household biomass fuel use and urbanicity on child anaemia in SSA. This study, therefore, seeks to investigate the joint effect of household biomass fuel use for cooking and urbanicity on anaemia among children under the age of 5 in SSA.

METHODS

Data and sampling

Nationally representative data from the Demographic and Health Surveys (DHS) Program for SSA countries from 2010 to 2019 were acquired for analysis in this study. The DHS Program provides large secondary data gathered from surveys using probability sampling methods, following standard protocols that are internationally accepted. Different sets of questionnaires designed and pre-tested to ensure reliability and amenability for comparison of data gathered on various spatial and temporal scales are used in the survey. Some questionnaires the program uses include the "Children's questionnaire" "Mother's questionnaire", "Men's questionnaire" and "Household questionnaire". These questionnaires cover a broad range of variables cutting across demographics and anthropometrics, water and sanitation, health, wealth, nutrition among others. The program recruits and trains field officers to collect accurate data and measurement of weight, height, anaemia using recommended guidelines and instruments. Data on other important variables such as household cooking fuel, urbanicity, wealth, water, and sanitation are taken at the household level. The dataset used in this study are: Children's Data - Children's Recode, and Household Data - Household Recode (variable names: caseid; v000; v001 v007; v013; v102; v113; v116; v136; v149; v151; v152; v190; bord; b4; b8; m19; hw2; v457; v005; hhid; hv001, hv000; hv226).

Study Countries

A sample of 123,182 was drawn from 29 countries (Figure 1) accros the five (5) geographic regions—Western, Eastern, Central and Southern Africa in SSA. For a country to be selected, it must meet the following criteria: should be found in SSA based on the United Nations regional groupings; it must have a DHS dataset with standardized questions and observations on anaemia level of children under five years as well as household cooking fuel type, urbanicity, source of drinking water and type of toilet facility. Where multiple datasets exist for a country, the most recent dataset is used.

Figure 1

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Table 1

Definition of important variables

The dataset provided information on household cooking fuel type, source of drinking water and toilet facility type at the household level. The observations for household cooking fuel were classified into "Clean" and "Unclean" (polluting fuels) following the criterion some studies [25,26] used (see Table 1). The weight of the child at birth named as "Birth weight" was categorized as "Underweight" (<2.5kg) and "Normal" (≥2.5kg) (see, [27]). Also, the observations for the household source of drinking water and type of toilet facility were classified into "improved" and "unimproved" using the revised definitions by the WHO/UNICEF Joint Monitoring Programme (JMP) report [28]. Table 2 summarises the descriptions of improved and unimproved sources of water and toilet facilities (see [29]) for explication of the categorisation of these critical basic services.

Table 2

Measures

Outcome variable

Anaemia status of children is the outcome variable considered in this study. According to DHS, the anaemia status of living children within the age bracket 0-4 years before the survey night was taken. It has its responses classified into four (4) categories according to the WHO recommendation as (i) "Not anaemic" for children with haemoglobin count(g/dl) measuring above 11g/dl; (ii) "Mild anaemia" for haemoglobin count of 10-10.9g/dl; (iii) "Moderate anaemia" for haemoglobin count between 7.0-9.9g/dl; and (iv) "Severe anaemia" for haemoglobin count less than 7.0g/dl. Children with no observations for anaemia count (not tested) and those whose mothers were not listed in the household questionnaire were excluded. Observations under mild, moderate and severe were combined and recoded as "1" for "Anaemic" and observations under not anaemic was recoded as "0" "Normal" (see [30]. This produced the dichotomous outcome variable "Aneamia status".

Main predictor variable

The predictor chosen for this study is a composite variable formed from the interactive effect of household cooking fuel type and urbanicity. The selection of the predictor variable was based on parsimony, literature review, theoretical relevance as well as practical significance. Household cooking fuel type and Urbanicity both had two categories since the former was classified as "Clean" and "Unclean" and the latter measured as "Rural" and "Urban" per the Demographic Health Survey (DHS). This, therefore, gave four mutually exclusive groups:

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Unclean-Urban (households relying on "unclean" cooking fuel and found in urban areas); Unclean-Rural (households relying on "unclean" cooking fuel and found in rural areas); Clean=Urban (households using "clean" cooking fuels and found in urban areas); and Clean-Rural (households using "clean" cooking fuels and found in rural areas). This variable combination technique has been widely applied in previous studies [29,31]. Out of the four responses, "Unclean-Urban" was chosen as the reference category in the models. The choice of the reference category was based guided by previous studies [32,33]. These authors explained that urban areas are considered as places with relatively higher levels of air pollution and its associated negative health outcomes, which has the potential of multiplied burden relative to child anaemia when households use unclean cooking fuels. This makes it prudent to use "Unclean Urban" as the reference category.

Covariates

There is a plethora of evidence on the independent associations between the type of household cooking fuel and urbanicity with child anaemia [14,22,33–35] Even though the UNICEF categorisation of the factors that influence the association between household cooking fuel and child anaemia—proximal, immediate and distal factors serves as a useful framework, for parsimony, practical and theoretical considerations we categorize independent variables drawn from literature under 'Individual-level characteristics", "Household characteristics" and " Contextual factors" (see [4,36] . The Individual-level characteristics considered in this study are Child age in years (0, 1, 2, 3 and 4); Sex of child (Male, Female); Birth order (1, 2, 3 and above); Perceived birth size (Larger than average, Average, Smaller than average, Don't know); Birth weight (Underweight, Normal); Age of the mother (15-19, 20-24, 25-29, 30-34, 35-39, 40-44, 45-49); BMI of the mother (Thin, normal and Obese); Education (No formal, Primary, Secondary and Tertiary); Marital status (Never married, Married, Living with a partner, widowed/divorced/separated); Employment status (No, Yes); Number of antenatal visits by mother "ANC" (No, Yes); Number of postnatal visits by mother "PNC" (No, Yes)

The relevant household-level included in this study are Wealth status (Poor, Middle, Rich); Household size ("Small" for those with 1-5 members; "Medium" 5-10 member, and "Large" for more than 10 members); Age of household head ("Young-aged adults" for those age below 35; "Middle-aged adults" for those between 35 to 64years; and "Old-aged adults" for those 65years and above); Sex of household head (Male, Female); Access to electricity (No, Yes); Type of toilet facility (Improved, Unimproved); Source of drinking water (Improved, Unimproved)

Finally, we adjusted for the effect of the Contextual factor "Geographic region" (Western Africa, Eastern Africa, Central Africa, Southern Africa). Variables in this category of factors relate to the attributes of respondent's neighbourhood, and opportunities and services that are space-bound [37,38].

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Data Analysis

The Stata version 14.0 MP(Stata Corporation,College Station, TX, USA) software was used for the analysis of data. The data was first declared as a survey dataset to prevent potential errors that could arise from the complex survey design using the "svyset" command with the cluster, weighting, and strata variables. To understand the distribution of childhood anaemia and the influence of predictive factors on anaemia, descriptive analysis was performed. Using ArcGIS 10.6, the data was integrated with ESRI Shapefiles to construct a map of the study countries showing the distribution of child anaemia. We then determined the associations between the anaemia status of children under five and the relevant predictors using the chi-square test of independence. These relationships were further examined by implementing five multilevel logistic regression models. The first model (Model 0) with no independent variable indicated the variance in child anaemia as a result of clustering of the primary sampling units (PSU). In Model I, only the main predictor variable (Urbanicity-Type of cooking fuel). Model II adjusted for the individual-level characteristics. The effects of both individual-level and the relevant household-level factors were adjusted in Model III. Model IV controlled the individual-level and household-level characteristics, and the contextual-level factors. The Akaike'sInformation Criterion (AIC) was the model comparison metric estimated. Results were present using odds ratios (OR) and adjusted odds ratios (aORs) at $p<0.05$ and 95% Confidence Intervals (CI).

Ethical considerations

We used datasets provided by the Demographic Health Surveys Program and have not had any form of contact with the study participants. The program obtains approval from the Ethics Boards of the various partner organisations and countries such as the Ministries of Health. The DHS Program recognizes and adheres to established international and local ethical standards and protocols in its surveys. The ICF International's Institutional Review Board (IRB) through The DHS Program's reviewed and approved all survey procedures and instruments used before implementation. The board aside from providing technical assistance to the program ensures that the survey complies with the United States Department of Health and Human Services regulations for the protection of human subjects CFR 46 as well as the laws of the individual countries. Further information regarding the DHS data usage and ethical standards can be accessed at https://dhsprogram.com/data/Access-Instructions.cfm.

Patient and public involvement

Patients and the public were not involved in the design and conduct of this research.

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RESULTS

Figure 2

Descriptive analysis

The study included 123,182 children under the age of 5 years from 29 SSA countries. The percentage of children who suffered anaemia was 64%. The prevalence of anaemia was high in children born to mothers in Western Africa (75%) and low among those born in Southern Africa (54%) (Figure2). A majority (68%) of the children included in the survey were in rural households that used unclean cooking fuels, 24% were aged 1, 51% were male, 48% were of second birth order, and 50% were average size at birth. Most of the children included in the survey were born to mothers aged 25-29 (27%), mothers with normal BMI (67%), mothers with no formal education (40%), married mothers (72%), employed mothers (64%), mothers who attended ANC (91%) and mothers who did not attend PNC (56%). A majority of the children belonged to poor households (45%), households with medium size (46%), households with Middle-aged adults heads (44%), households with male heads (81%), households with no access to electricity (70%), households with an unimproved toilet facility (56%), and households with improved drinking water (65%). Most of the children included in the study were in Western Africa (40%) and Eastern Africa (40%). Significant differences in the distribution of anaemia status was found in all the in predictor variables, except PNC attendance (Table 2).

Table 2

Multivariate analysis

Table 3 shows the multilevel logistic regression results on the joint effect of urbanicity and type of household cooking fuel on childhood anaemia in SSA. In Model IV, the final model that controlled for all the variables including country, it was found that children from rural households that depend on unclean cooking fuels [aOR=1.120; 95% CI=1.033-1.214] and rural households that depend on clean cooking fuels [aOR=1.256; 95% CI=1.080-1.460] were more likely to be anaemic as compared to children from urban households using clean cooking fuel.

The odds of suffering from anaemia decreased with the age of the child. It was found that children aged 4 had the lowest odds [aOR=0.264; CI=0.247-0.283] of suffering from anaemia compared with those less than 1 year (0). Female children were less likely to be anaemic compared to male children [aOR=0.857; CI=0.829-0.887]. Children with three or more birth order were more likely to be anaemic compared to first birth order children [aOR=1.269; CI=1.179-1.367]. Children with smaller than average birth size were more likely to be anaemic compared to those who were larger than average [aOR=1.075; CI=1.020-1.132].

The odds of anaemia in children under five was lower among those born to mothers aged 45-49 compared to those aged 15-19 [aOR=0.559; CI=0.484-0.645]. Children born to mothers with

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normal BMI were less likely to be anaemic compared to born to children with thin mothers [aOR=0.923; CI=0.870-0.979]. Children born to mothers with tertiary educational level were less likely to be anaemic compared to those whose mothers had no formal education [aOR=0.534; CI=0.480-0.595]. Children born to widowed/divorced/separated mothers were more likely to be anaemic compared to those who were never married [aOR=1.102; CI=1.003-1.211]. Children born to mothers who attended ANC were less likely to be anaemic compared to those who never attended ANC [aOR=0.931; CI=0.874-0.991].

The odds of anemia in children under five was lower among children born to mothers in rich households compared to those born to mothers in poor households [aOR=0.888; CI=0.844-0.935]. Children born to mothers in larger households were more likely to be anaemic compared to those born to mothers in small households [aOR=1.240; CI=1.163-1.321]. Children born to mothers in households with access to electricity were less likely to be anaemic compared to those born to mothers in household without access to electricity [aOR=0.896; CI=0.853-0.941]. Children born to mothers who lived in households with improved source of drinking water were less likely to be anaemic compared to those born to mothers who lived in households with unimproved source of drinking water [aOR=1.046; CI=1.008-1.086]. Compared to children born to mothers who live in Western Africa, those born to mothers who live in Southern Africa were less likely to be anaemic [aOR=0.497; CI=0.451-0.548] (see Table 3).

Table 3

DISCUSSION

In this current study, our principal aim was to investigate the association between household biomass fuel use, and the joint effect of household biomass fuel use for cooking and urbanicity on anaemia among children under the age of 5 in SSA. The study showed that children from rural households that depend on unclean cooking fuels were more likely to be anaemic compared with children from urban households using unclean cooking fuel. This is in line with previous studies in various parts of the world such as Timor-Lest [21] and India [16,22]. Although this study was a cross-sectional study and could not claim causality, some studies [16] have explained that exposure to unclean cooking fuels may lead to systemic inflammation which is regarded as a popular cause of anaemia, mediated by inflammatory cytokines such as tumour necrosis factor-alpha (TNF-α), interleukin-1 (IL-1), interleukin-6 (IL-6), and interferon-γ (IFN-γ) [16,39]. The pathways by which these causes anaemia is that IL-6 increases with alveolus inflammation related to biomass pollution and hepcidin goes down, that stop the movement of Fe, causing anemia by inflammation [16,39]. Apart from the key independent variable, we controlled for other key factors associated with anaemia among children under five which are worth discussing in light of previous evidence.

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We found that the birth weight of the child had a statistically significant association with anaemia. Specifically, children with normal weight had lower odds of being anaemic compared with underweight children. This aligns with previous studies in Ethiopia [40] and Brazil [41]. Some previous studies espoused that there is a direct link between food consumption and anaemia. Due to this, in a household where there is no food security, it can affect the nutritional status of children, which could contribute to anaemia [42,43]. Relatedly, we found that children in large households had higher odds of suffering from anaemia compared to those in a small household. This finding confirms a previous study in Ethiopia [44]. Insufficient consumption of appropriate quantity of nutrients due to the high numbers in the households could possibly account for this observation as explained by [44].

The study also established that the socio-economic status (education and wealth) of women had a statistically significant association with child anaemia. Specifically, it was found that children whose mothers are in the rich wealth status, as well as those with tertiary level of education, have lower odds of being anaemic. This corroborates several previous studies in SSA and other countries such as Ethiopia [40,45,46], Brazil [47], Switzerland [48], Burma [49], and India [50]. There are three pathways to the explanation of this finding. First, on the supply side, children from households with high-socio economic status can buy nutritious foods for their children, unlike the poor ones who might not be able to afford three square meals a day. In other words, the poor might lack the resources to purchase nutritious foods for their children. Second, evidence also suggests that mothers in poor households are also anaemic and the probability of their children also being anaemic is high. Thirdly, in terms of education, mothers who are highly educated can translate the health education they receive during child welfare clinics into practice. Besides, those who are highly educated can recognise danger signs related to childhood illnesses that warrant emergency care [44,51].

Another major finding in our study was that the odds of suffering from anaemia decreased with the age of the child. This finding is supported by other studies conducted in Ethiopia [40,42,52,53], Ghana [54], and Uganda [55]. This observation is expected due to the fact that children have their least Hb value at six month and they continue increasing their values as they age [56]. We also observed a statistically significant association between maternal age and child's anaemia. Specifically, children whose mothers are aged 45-49 and those aged 30-34 had the lowest odds of being anaemic. This is consistent with previous studies in Ethiopia [44]. It is possible that as mothers advance in age, they gain experiences with childcare and also, they are more likely to be exposed to education on appropriate practices on childhood nutrition compared with those who are adolescents. In line with a previous study [57], we also found that children in female-headed households, middle-aged adults, old age adults were more likely to be anaemic compared with those in male-headed households; and households headed by young adults. Surprisingly, our study showed that children in households with an improved source of drinking water had higher odds of being anaemic. This is contrary to other empirical studies in Bangladesh [58], India [22], Benin and Mali [59]. Longitudinal case-control studies coupled with qualitative evidence are needed to unravel this counter-intuitive finding.

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It is worthy to discuss the methodological limiations inherent in this study. First, although we controlled for several confounders, we could only control for those that were in the dataset. Second, various contextual issues could possibly explain the results we obtained from this study, nonetheless, we used multi-level analysis to account for the contextual variations. The study is also limited by the cross-sectional nature of the design employed for the data collection. Due to this, it is impossible to detect temporality of sequence [60]. There is also the possibility of error in measurement of the Hb levels, however this is likely to be minimal since DHS uses standardized instruments across surveys and also uses experienced and well trained data collectors. We did not also control for the dietary pattern and nutritional intake because the data are available for only children aged 6–23 months. In addition, we did not control for child's fever, diarrhea, and Acute Respiartory Infection with anemia since there are variations in the context, year, and season of data collection across the surveys [60,61].

CONCLUSION

Our study found that there is an association between the joint effect of household biomass fuel use for cooking and urbanicity and anaemia among children under the age of 5 in SSA. Apart from this we also found that birth weight of the child, age of the child, maternal age, sex of household head, age of household head, maternal education, wealth status, size of household, type of source of drinking water and country of residence are associated with childhood anaemia. The following recommendations are therefore made for policy and practice. Firstly, it is critical to promote clean fuel usage among households and women in rural areas. This could be done by governments in various countries by enhancing access and subsidising the cost of natural and or, liquified petroleum gas [LPG] and cylinders. It is, therefore, imperative to also improve road networks which can easily lead to accessible markets. Second, it is also imperative to advocate for improvement in female education which could lead to an improvement in the socio-economic status of the women. Thirdly, there is the need for the installation of improved biomass stoves. Also, maternal education by community health nurses on the risk factors of anaemia is also strongly suggested. Stakeholders that seek to improve maternal and child health could also consider these associated factors.

Abbreviations

CI: Confidence interval
DHS: Demographic health survey
SSA: sub-Saharan Africa
PM: Particulate Matter
WHO: World Health Organization

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Contributorship statement

IA conceptualized and designed the study. IA and AA performed the analysis. IA, AS, AA, BOA and SY drafted the initial draft. AS, AA, BOA and SY provided technical support and critically reviewed the manuscript for its intellectual content. SY had the final responsibility to submit for publication. All authors read and amended drafts of the paper and approved the final version.

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Competing interest: None

Patient consent: Not applicable

Ethics approval

Ethics approval was not required for this study since the data is secondary and is available in the public domain. More details regarding DHS data and ethical standards are available at: http://goo.gl/ny8T6X.

Provenance and peer review: Not commissioned; externally peer-reviewed

Data sharing statement

Data for this study were sourced from Demographic and Health surveys (DHS) and available here: http://dhsprogram.com/data/available-datasets.cfm.

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Tables

Table 1: Classification of the source of drinking water and toilet facilities under the WHO/UNICEF Joint Monitoring Programme and cooking fuel.

Service	Improved/Clean	Unimproved/Unclean
Drinking water sources	Piped water, boreholes or tube wells, protected dug wells, protected springs, rainwater, and packaged or delivered water.	Unprotected dug well, unprotected spring, river, dam, lake, pond, stream, canal and irrigation canal
Type of toilet facilities	Flush/pour flush to piped sewer systems, septic tanks or pit latrines, ventilated improved pit latrines, composting toilets or pit latrines with slabs.	Pit latrines without a slab or platform, hanging latrines or bucket latrines and open defecation.

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Cooking fuel type	Electricity, liquid petroleum gas (LPG), natural gas and biogas	Kerosene, coal/lignite, charcoal, wood, straw/shrubs/grass and animal dung

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Table 2: Distribution of child anaemia status by predictor variables.

Variable	Weighted n	Weighted %	Anemia status		Variable	Weighted n	Weighted %	Anemia status	
			Normal (%)	Anemic (%)				Normal (%)	Anemic (%)
Key predictor									
Urbanicity-Type of cooking fuel (p<0.001)					**Employment status (p<0.001)**				
Urban-Unclean	27,280	22	38	62	No	44,403	36	34	66
Urban-Clean	10,480	9	43	57	Yes	77,975	64	36	64
Rural-Unclean	83,261	68	34	66	**ANC (p<0.001)**				
Rural-Clean	1,388	1	42	58	No	7,823	10	26	74
Individual-level characteristics					Yes	74,542	91	34	66
Child age (p<0.001)					**PNC (p= 0.534)**				
0	14,807	12	21	79	No	43,739	56	32	68
1	28,811	24	25	75	Yes	34,884	44	32	68
2	26,779	22	36	64	**Household-level characteristics**				
3	26,716	22	43	57	**Wealth (p<0.001)**				
4	25,304	21	49	51	Poor	54,683	45	31	69
Sex of child (p<0.001)					Middle	24,810	20	35	65
Male	61,873	51	34	66	Rich	42,922	35	41	59
Female	60,543	49	37	63	**Household size (p<0.001)**				
Birth order (p<0.001)					Small	49,586	41	38	62
1	25,382	21	37	63	Medium	56,844	46	35	65
2	59,156	48	36	64	Large	15,986	13	28	72
3 and above	37,878	31	33	67	**Age of household head (p<0.001)**				
Perceived birth size (p<0.001)					Young-aged adults	52,244	43	36	64
Larger than average	40,251	34	36	64	Middle-aged adults	54,249	44	35	65

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Average	58,862	50	36	64	Old-aged adults	15,921	13	33	67
smaller than average	17,668	15	34	66	**Sex of household head (p<0.001)**				
Don't know	1,675	1	29	71	Male	98,700	81	35	65
Age of mother (p<0.001)					Female	23,716	19	38	62
15-19	5,903	5	25	75	**Access to electricity (p<0.000)**				
20-24	25,845	21	32	68	No	85,532	70	34	66
25-29	33,385	27	36	64	Yes	36,875	30	40	60
30-34	26,993	22	37	63	**Type of toilet facility (p<0.001)**				
35-39	18,763	15	38	62	Improved	54,271	44	40	60
40-44	8,814	7	39	61	Unimproved	68,135	56	32	68
45-49	2,714	2	38	62	**Source of drinking water (p<0.001)**				
BMI of mother (p<0.001)					Improved	79,965	65	36	64
Thin	10,392	10	30	70	Unimproved	42,441	35	34	66
Normal	70,647	67	34	66	**Contextual factor**				
Obese	24,433	23	43	57	**Geographic region(p<0.001)**				
Education (p<0.001)					Western Africa	49,028	40	25	75
No formal	48,650	40	28	72	Eastern Africa	48,674	40	44	56
Primary	41,673	34	40	60	Central Africa	21,729	18	37	63
Secondary	28,670	23	42	58	Southern Africa	2,986	2	46	54
Tertiary	3,423	3	52	48	N	123,182			
Marital status (p<0.001)									
Never married	6,468	5	36	64	Anaemia status				
Married	87,591	72	35	65					
Living with a partner	20,322	17	38	62	Normal	44,403	36		
Widowed/divorced/separated	8,036	7	39	61	Anaemic	77,975	64		

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Table 3. Multilevel logistic regression results on the joint effect of urbanicity and type of household cooking fuel on childhood anaemia

Variables	Model 0		Model I			Model II			Model III			Model IV		
	OR	(95% CI)	aOR	95% CI		aOR	95% CI		aOR	95% CI		aOR	95% CI	
Fixed effects														
Urbanicity-Type of cooking fuel														
Urban-Clean			1			1			1			1		
Urban-Unclean			1.350***	1.286	1.418	1.229***	1.145	1.320	1.206***	1.122	1.297	1.063	0.987	1.146
Rural-Unclean			1.673***	1.600	1.750	1.211***	1.129	1.299	1.115**	1.032	1.205	1.120**	1.033	1.214
Rural-Clean			1.273***	1.144	1.416	1.317***	1.136	1.526	1.239**	1.067	1.438	1.256**	1.080	1.460
Child age														
0						1								
1						0.803***	0.762	0.847	0.804***	0.762	0.847	0.799***	0.758	0.844
2						0.498***	0.471	0.362	0.500***	0.473	0.528	0.493***	0.466	0.521
3						0.341***	0.321	0.362	0.345***	0.325	0.367	0.342***	0.322	0.364
4						0.261***	0.244	0.279	0.265***	0.247	0.284	0.264***	0.247	0.283
Sex of child														
Male						1			1			1		
Female						0.862***	0.834	0.891	0.861***	0.833	0.890	0.857***	0.829	0.887
Birth order														
1						1			1			1		
2						1.152***	1.092	1.216	1.124***	1.065	1.186	1.121***	1.061	1.184
3 and above						1.397***	1.302	1.498	1.258***	1.170	1.353	1.269***	1.179	1.367
Perceived birth size														
Larger than average						1			1			1		
Average						1.004	0.968	1.041	1.015	0.978	1.053	1.052**	1.014	1.093

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smaller than average						1.026	0.975	1.08	1.026	0.975	1.080	1.075**	1.020	1.132
Don't know						1.184*	1.009	1.39	1.178*	1.003	1.384	1.129	0.960	1.328
Age of mother														
15-19						1			1			1		
20-24						0.802***	0.735	0.875	0.834***	0.763	0.910	0.869***	0.795	0.950
25-29						0.658***	0.600	0.722	0.689***	0.628	0.756	0.733***	0.667	0.806
30-34						0.586***	0.532	0.647	0.608***	0.550	0.671	0.667***	0.603	0.737
35-39						0.538***	0.484	0.597	0.543***	0.488	0.604	0.602***	0.540	0.671
40-44						0.526***	0.469	0.59	0.526***	0.468	0.592	0.599***	0.532	0.675
45-49						0.497***	0.433	0.572	0.493***	0.428	0.568	0.559***	0.484	0.645
BMI of mother														
Thin						1			1			1		
Normal						0.955	0.901	1.012	0.970***	0.915	1.028	0.923**	0.870	0.979
Obese						0.816***	0.765	0.871	0.841***	0.787	0.898	0.780***	0.730	0.834
Education														
No formal						1			1			1		
Primary						0.531***	0.509	0.554	0.56803	0.545	0.592	0.779***	0.745	0.815
Secondary						0.502***	0.479	0.527	0.54016	0.514	0.567	0.676***	0.642	0.713
Tertiary						0.392***	0.354	0.435	0.43671	0.393	0.485	0.534***	0.480	0.595
Marital status														
Never married						1								
Married						1.071	0.996	1.152	1.161***	1.074	1.255	1.030	0.951	1.116
Living with a partner						0.975	0.900	1.057	1.044	0.958	1.137	1.036	0.949	1.131
Widowed/divorced/separated						0.979	0.893	1.072	1.062	0.968	1.165	1.102*	1.003	1.211
Employment status														
No						1								
Yes						0.968	0.934	1.004	0.982	0.947	1.018	0.911***	0.878	0.946

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Antenatal care														
No						1								
Yes						0.912**	0.857	0.969	0.940*	0.884	1.000	0.931*	0.874	0.991
Wealth														
Poor									1					
Middle									0.928**	0.885	0.973	0.917***	0.874	0.962
Rich									0.830***	0.790	0.873	0.888***	0.844	0.935
Household size														
Small									1			1		
Medium									1.109***	1.066	1.156	1.095***	1.051	1.142
Large									1.472***	1.383	1.566	1.240***	1.163	1.321
Age of household head														
Young-aged adults									1					
Middle-aged adults									1.087***	1.041	1.136	1.012	0.968	1.058
Old-aged adults									1.088**	1.026	1.153	0.966	0.910	1.025
Sex of household head														
Male									1					
Female									0.945**	0.903	0.989	0.966	0.923	1.011
Access to electricity														
No									1					
Yes									1.090***	1.039	1.143	0.896***	0.853	0.941
Type of toilet facility														
Unimproved									1					
Improved									0.856***	0.824	0.889	0.927***	0.892	0.963
Source of drinking water														
Unimproved									1					
Improved									1.046**	1.008	1.085	1.046**	1.008	1.086
Geographic region														

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Western Africa												1		
Eastern Africa												0.397***	0.380	0.415
Central Africa												0.562***	0.532	0.595
Southern Africa												0.497***	0.451	0.548
Random effects														
PSU Variance (95% CI)	0.02(0.02-0.03)		0.01(0.02-0.03)			0.02(0.01-0.03)			0.02(0.01-0.03)			0.02(0.01-0.03)		
ICC	0.007		0.007			0.006			0.005			0.005		
LR Test	157.11***		162.27***			33.77***			32.09***			31.14***		
Wild χ2	Reference		638.08***			5397.49***			5699.37***			7017.31***		
Model fitness														
Log-likelihood	- 7995 2		-79633.85			-41560.3			-41341.3			-40448.4		
AIC	2E+0 5		159277.7			83182.53			82764.6			80984.8		
Number of clusters	1,382		1,382			1,382			1,382			1,382		

1=Ref, AOR=Adjusted Odds Ratio; CI=Confidence Interval
*p<0.05 **p<0.01 ***p<0.001

Figure Legends

Figure 1: Map of study countries

Figure 2: Map of study countries showing the distribution of child under age five years anaemia status

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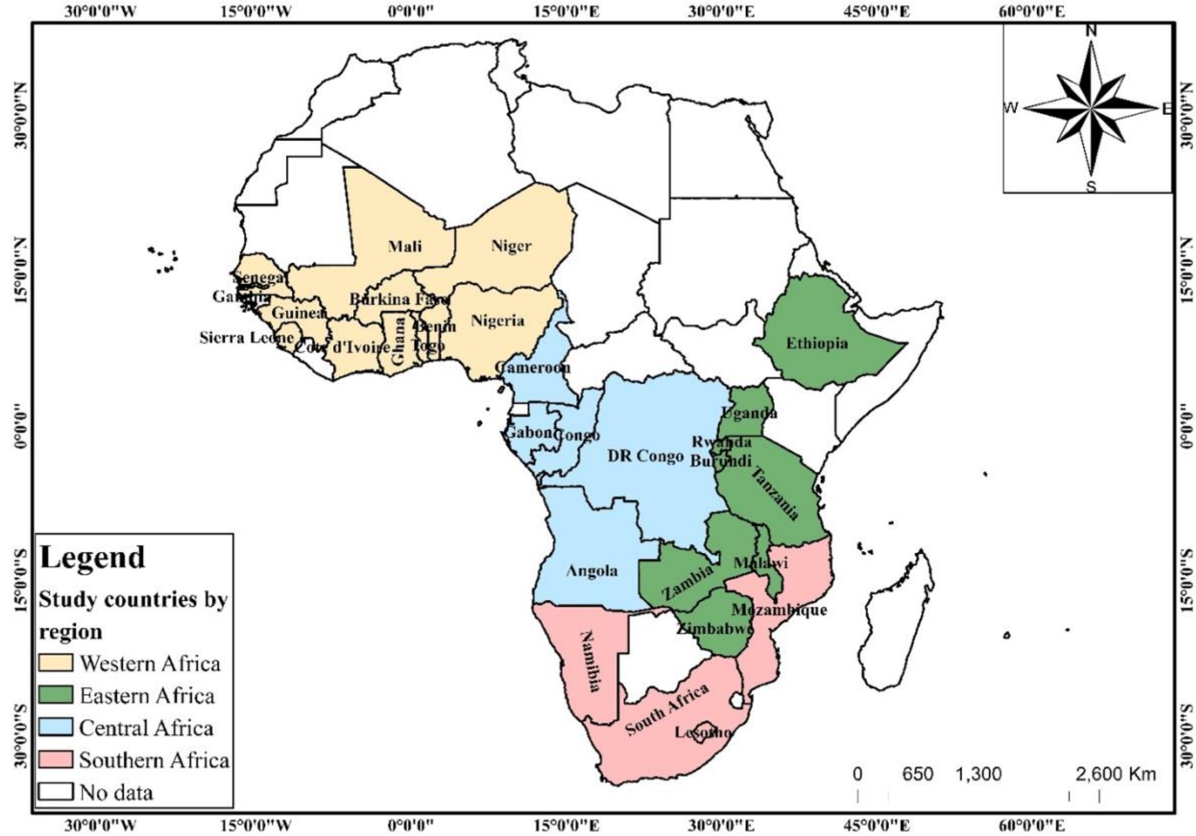

Figure 1: Map of study countries

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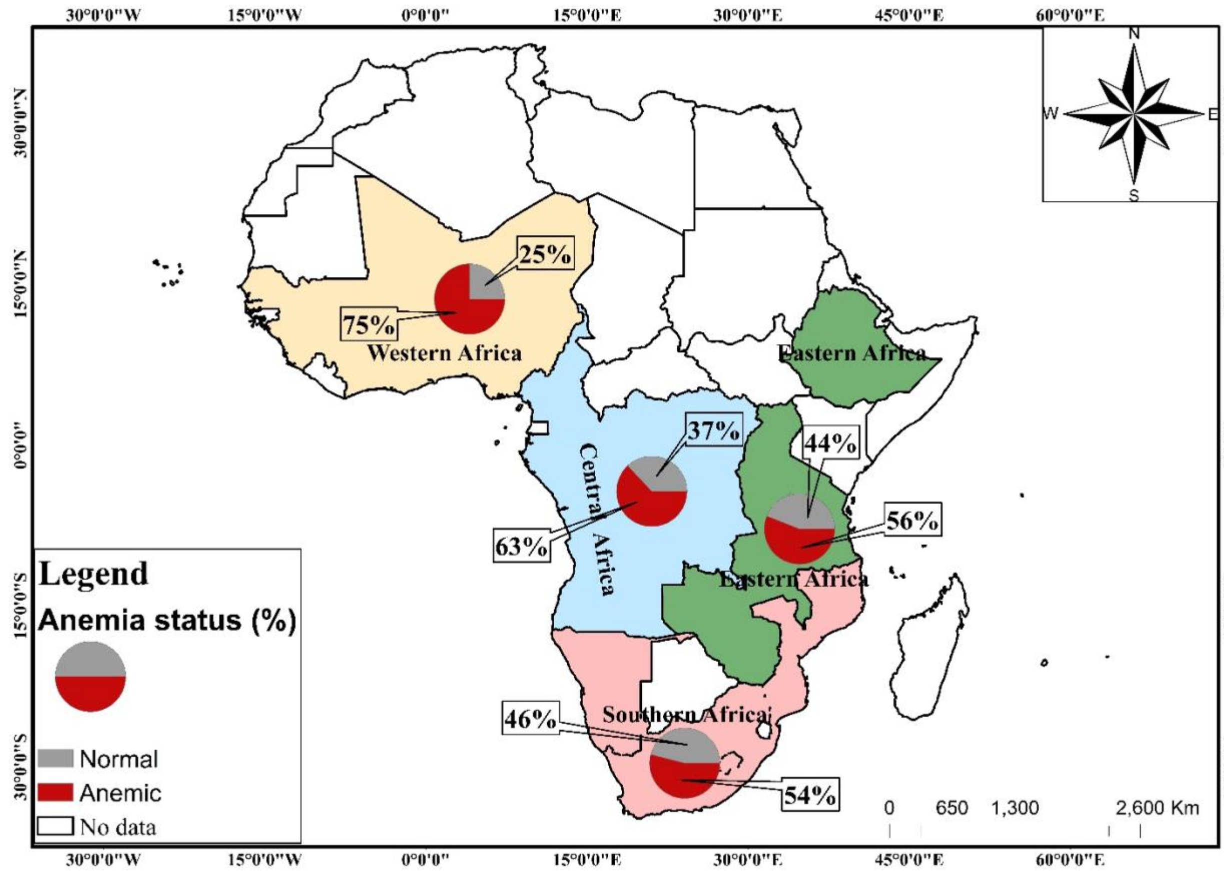

Figure 2: Map of study countries showing the distribution of child under age five years anaemia status

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