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DRIVERS OF ANAEMIA REDUCTION AMONG WOMEN OF REPRODUCTIVE AGE IN THE EASTERN AND UPPER WEST REGIONS OF GHANA: A SECONDARY DATA ANALYSIS OF THE GHANA DEMOGRAPHIC AND HEALTH SURVEYS

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ABSTRACT

Anaemia among women of reproductive age (WRA) increases the risk of pregnancy-related morbidity, mortality, and poor pregnancy outcomes. Globally, there is growing interest to reduce anaemia among WRA. In Ghana, anaemia among WRA declined at the national level between 2008 (59%) and 2014 (42%). There were also important declines at the sub-national level. The Eastern region (in the south) and Upper West region (in the north) provide an interesting opportunity to understand the decline. Identifying the drivers of anaemia reduction among WRA in Ghana provides important implementation science evidence for designing effective interventions. This current study examined the drivers of reduced anaemia prevalence in women of reproductive age using data from the Ghana Demographic and Health Surveys for 2008 and 2014. Anaemia was diagnosed as haemoglobin<12.0g/dl. Data were summarized using proportions and 95% confidence intervals. A weighted binary logistic-based multivariate decomposition technique was used to identify the potential drivers of anaemia across surveys for 2003, 2008 and 2014. Sensitivity analysis was carried out to test the robustness of the results of the decomposition analysis using haemoglobin concentration. The results of the decomposition analysis were presented as endowment and coefficient effects. Statistical analysis was carried out using Stata version 15. There was an improvement in access to water and sanitation, health services, family planning, and health insurance across surveys. Drivers of anaemia reduction over time at the national level included wealth index and maternal age, education, use of hormonal contraception and body mass index (BMI). In the Eastern region, the drivers of change were household wealth index, maternal age, hormonal contraceptive use and BMI. The drivers of change in the Upper West region, were household access to water, maternal education and BMI. The findings suggest that multi-level interventions are needed across sectors to further reduce anaemia among WRA.

Key words: Anaemia, Women, Nutrition, Reproductive-age, Ghana, Haemoglobin, Regression, Decomposition analysis

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INTRODUCTION

Anaemia among women of reproductive age (WRA) is a key public health challenge linked with adverse health, nutrition, social, and economic challenges [1]. Anaemia increases the risk of pregnancy-related morbidity, mortality, and poor pregnancy outcomes such as low birth weight and stunted growth in children [2,3]. There is growing global interest [4] to reduce anaemia among WRA by half (Sustainable Development Goals indicator 2.2.3) [5].

A third (29.9%) of WRA are anaemic [6], representing more than half a billion women worldwide. Anaemia prevalence is classified as severe and moderately severe in many developing countries including Ghana. The anaemia prevalence is higher in pregnant (36.5%) than in non-pregnant women (29.6%) [7]. Worldwide, there was a slight decline in moderate (14% in 2000 to 13% in 2019) and severe (2% in 2000 to 1% in 2019) anaemia prevalence among WRA in 2019 [8]. Key drivers to this reduction included actions addressing both nutrition-specific (iron supplementation and provision of micronutrient powders) and nutrition-sensitive interventions (biofortification, distribution and use of insecticide-treated nets) [8–10].

In Ghana, anaemia among WRA at the national level declined between 2008 (59%) and 2014 (42%) [11,12]. The decline was also observed at the sub-national levels. The Eastern region (ER) in the southern part of Ghana had a decline from 58% in 2008 to 39% in 2014, and the Upper West region (UWR) in the north from 70% in 2008 to 36% in 2014. These two regions have been exposed to large population-based nutrition-specific and sensitive interventions [13–16] whiles the standard anaemia interventions are nationwide. This decline provides an opportunity to understand the drivers of reduced anaemia prevalence among WRA to inform programming at the sub-national level. Therefore, the current study examined the drivers of reduced anaemia prevalence in WRA using data from the Ghana Demographic and Health Surveys for 2003, 2008 and 2014.

MATERIALS AND METHODS

Dataset source

The current study used nationally-representative data from the Ghana Demographic and Health Survey (GDHS) years 2003, 2008, and 2014. The GDHS is a nationally representative survey of Ghana. The data comprised women of reproductive age (15-49 years).

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Sampling design of the GDHS

A multi-stage stratified cluster sampling technique was used to select participants for the surveys [9,10,17]. First, there was a selection of enumeration areas (EAs), followed by stratification and proportionate sampling from each stratum using a probability proportionate to size. Then, 20-30 households were systematically sampled from each EA by listing the households in the selected EAs and households were randomly selected from the list for the survey. Further details are referenced here [9,10,17].

Eligible women were those between ages 15-49 years and were permanent residents or visitors who stayed in the selected households the night before the survey. Anaemia testing and anthropometric data (height and weight) were collected from a subsample of the eligible women who consented to be interviewed and tested [9,10,17].

The 2003 GDHS included haemoglobin concentration and anaemia data from 5278 WRA (92.7% response rate). The 2008 GDHS included haemoglobin concentration and anaemia status of 4,758 WRA (response rate of 96.8%). The 2014 GDHS included 4704 WRA's anaemia and haemoglobin data (50.1% response rate). A pooled dataset of n= 14,740 women aged 15-49 years was included in this current analysis (Appendix 1).

Outcome measures

Anaemia status was used as the outcome measure for this study. Anaemia was determined using haemoglobin (Hb) concentration measured using a battery-operated portable HemoCue analyzer. Anaemia was classified using altitude-adjusted haemoglobin (Hb) level for women not pregnant as Hb <12.0g/dl and for pregnant women, anaemia was Hb <11.0g/dl. Anaemia status was further classified as severe <7.0g/dl; moderate 7.0-9.9g/dl; or mild anaemia 10.0-11.9g/dl for not pregnant and 10.0-10.9g/dl for pregnant women. Haemoglobin concentration was used in sensitivity analysis to test the robustness of the results of the decomposition analysis, using anaemia status.

Covariates

The selection of the covariates was informed by the UNICEF conceptual framework [18] of factors affecting undernutrition, and findings of published studies reporting covariates of anaemia among WRA [19–25]. The data included household- as well as individual-level variables. The household-level variables included household size; sex of household head; socio-economic status; urban/rural residence; region; access to improved water sources; household toilet

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facilities and the number of insecticides treated bed nets. The individual-level variables were anaemia status, current age, religion, marital status, parity, ethnicity, age, educational level, hormonal contraceptive use, and possession of a valid National Health Insurance (NHI) card [9,10,17].

Statistical analysis

Data management and analyses were carried out using Stata version 15 [26]. All statistical analyses accounted for the complex survey structure by adjusting for the survey weighting for each survey year. For the pooled data analysis, the standard survey weight was denormalised by dividing the survey's standard weight by the survey sampling fraction that is the proportion of all women aged 15 to 49 years who were interviewed during the survey year to all women at the time of the survey). The GDHS datasets were used to determine the total number of women aged 15 to 49 years who were interviewed during the survey year, and OurWorldinData [27] was used to determine the total number of women aged 15 to 49 years who were living in the nation (Ghana) at the time of the survey. This is represented by the formula:

$$\frac{\text{women sampling weight from in the DHS} \times \text{total females aged } 15-49 \text{ in the country during the survey}}{\text{number of females aged } 15-49 \text{ interviewed in the survey}}$$

The analysis was carried out in two phases: the national level where data from all women aged 15- 49 years who participated in the study across all the regions were included. The second stage included participants from only the Eastern and Upper West regions of Ghana.

Descriptive statistics were presented in terms of proportions and 95% confidence intervals. Rao-Scott χ^2 test statistics was used to test for associations between the independent characteristics and anaemia status of the women. A weighted binary logistic-based multivariate decomposition technique [28] was used to quantify the contribution of selected variables to the change/reduction in anaemia prevalence between 2008 and 2014 at the national level and for the Eastern and Upper West regions.

Sensitivity analysis was carried out using haemoglobin concentration to test the robustness of the results of the decomposition analysis. The results of the decomposition analysis were presented as endowment and coefficient effects. The endowment effect explains how much the changes in the level of the explanatory variables between 2008 and 2014 contribute to the observed difference in anaemia and mean Hb level between 2008 and 2014. The coefficient effect measures the

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contribution of differences in the coefficients (including differences in the intercept) to the observed difference in the mean Hb level between 2008 and 2014.

The interaction term accounts for the fact that differences in endowments and coefficients exist simultaneously between 2008 and 2014. Following binary analysis, the variables -household wealth index, current age, maternal educational level, hormonal contraceptive use and BMI were selected for decomposition analysis for the national level and Eastern Region. For the Upper West Region, variables selected were household access to improved water sources, maternal education, and BMI. Contributions of each covariate were reported in terms of coefficients and percentages.

RESULTS AND DISCUSSION

The findings provide background characteristics of the study population and the changes in anaemia prevalence between 2003 to 2014 among selected households and individual-levelled characteristics. The drivers (variables) of the changes and decline in anaemia prevalence and haemoglobin concentration between 2008 and 2014 for the national level, Eastern and Upper West regions of Ghana are also presented.

Selected household and maternal/individual-levelled characteristics

The mean age of the household heads was 43.8 (± 13.7) years and a higher proportion (61.6%) of households were headed by males. About four out of every ten (44.4%) households had less than 5 members. More than two-thirds of the households had access to improved drinking water (87.7%) Use of insecticide-treated bednets, improved over the years from 2003 (19.3%) to 2014 (75.1%).

The mean age of the women was 29.2 (± 9.4) years. Close to half (47.6%) of the women were currently married. More than half of the women had up to secondary level education. Sixty percent of the women had normal body size while three in every ten women were either overweight (BMI>25kg/m^2) or obese (BMI>30kg/m^2). Most of the women had between one and four children each. About 20% were currently breastfeeding. Appendix 2 provides further details of the household and maternal/individual-levelled characteristics.

Levels, trends, and differences in maternal anaemia status between surveys

The prevalence of maternal anaemia at the national level has been fluctuating over the past decades (Figure 1). In 2003, the prevalence was 44.6% [95%CI:42.8,46.4] but increased to 58.7% [95%CI:56.7,60.7] in 2008. Thus, there was a 14.1% points

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increase in anaemia among women between 2003 to 2008. In 2014, the level of maternal anaemia declined to 42.4% [95%CI: 40.5,44.2], thus, a 16.3% points reduction from 2008. The reduction in maternal anaemia between 2003 and 2014 was 2.2% points (Appendices 3 and 4).

Overall, except for the sex of the household head, marital status, ethnicity, parity, and the number of children alive, the prevalence of maternal anaemia was significantly different across all levels of the variables studied ($p<0.05$). Consistently, the prevalence of maternal anaemia was relatively lower among women who use hormonal contraception. The prevalence of maternal anaemia decreased among WRA with higher educational levels across survey years. Appendix 3 provides details of the prevalence of anaemia among selected households and individual-levelled characteristics, and Appendix 4, the changes in reduction over the survey periods of study.

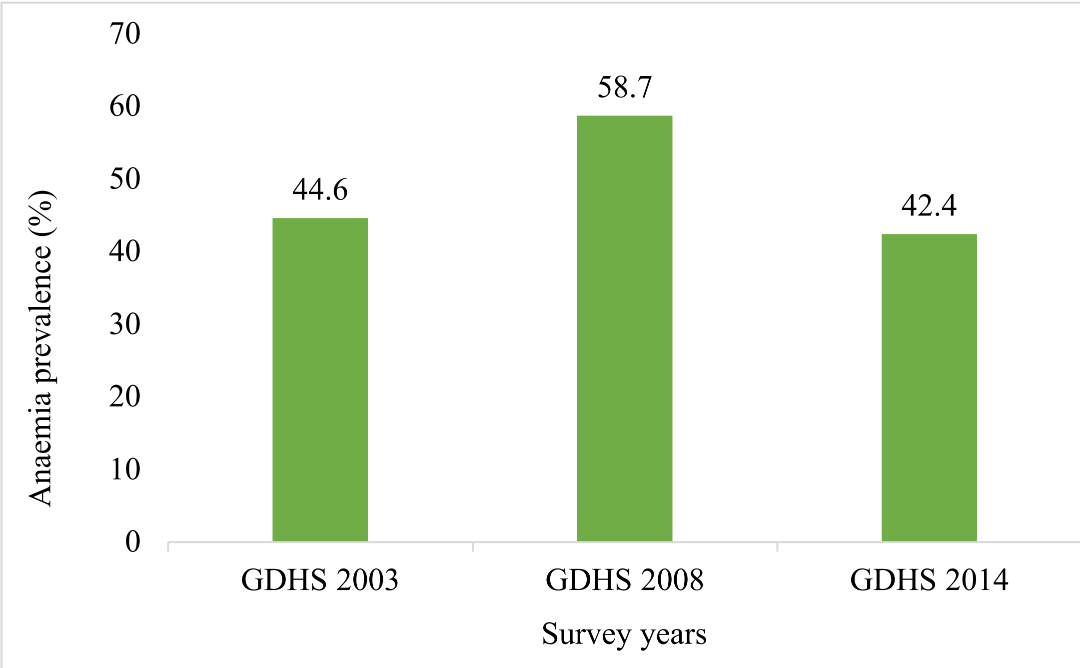

Figure 1: Changes in maternal anaemia prevalence between 2003 and 2014 at the national level

Drivers of reduced anaemia (decomposition analysis results)

The multivariate decomposition analysis identified the drivers of the reduction in maternal anaemia prevalence between the survey periods 2008 and 2014. At the national level, changes in the characteristics (endowments) of the participants were associated with a reduction in maternal anaemia by 0.01471 representing

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9.04% (p<0.001) whiles the size of the effect of all the characteristics (coefficients) was associated with a decline of 0.14806 representing 90.96%. Changes in the proportion of hormonal contraceptive use were associated with a 1.5% reduction in maternal anaemia. Changes in the distribution of maternal BMI status were associated with a 5.05% reduction in maternal anaemia. In the sensitivity analysis using haemoglobin concentration as the outcome, 9.8 % of the changes in characteristics (endowments) were associated with a reduction in maternal anaemia by 0.047 whiles the size of the effect (coefficients) was associated with a reduction of 0.592 representing 90.2%. Details of the decomposition analysis are shown in Table 1 and Appendix 7.

In the Eastern Region, the variables studied were associated with changes in the distribution of the characteristics (endowment) to the decline of anaemia by 0.01164 representing a 5.99% reduction while the size of the effect of all the characteristics (coefficients) was associated with a decline by 0.18271 representing 94.01% of maternal anaemia between 2008 and 2014 survey periods. Changes in the proportion of hormonal contraceptive use were associated with a 0.002 reduction (1.03%) of maternal anaemia. In the sensitivity analysis using haemoglobin concentration as the outcome, 6.1 % of the changes in characteristics (endowments) were associated with a reduction in maternal anaemia by 0.015 whiles the size of the effect (coefficients) was associated with a reduction of 0.601 representing 93.9% (Appendices 5 and 7).

In the decomposition analysis for the Upper West Region, the variables studied were associated with a 0.0173 (5.48%; p<0.050) reduction to changes in the distribution of the characteristics (endowment) of maternal anaemia between 2008 and 2014; whiles the size of the effect of all the characteristics (coefficients) was associated with 0.29836 (94.52%) decline (Table 3). Changes in the proportion of access to improved water sources were associated with a 1.09% reduction in maternal anaemia. Maternal education was associated with 1.49% of the reduction in maternal anaemia. For the sensitivity analysis using haemoglobin concentration as the outcome, 6.7 % of the changes in characteristics (endowments) were associated with a reduction of maternal anaemia by 0.019 whiles the size of the effect (coefficients) was associated with a reduction of 1.149 representing 93.3% (Appendices 6 and 7).

The current study examined and described the drivers of reduced anaemia prevalence among WRA at the national and sub-national levels in the northern and southern parts of Ghana using data from the Ghana Demographic and Health Surveys for 2003, 2008 and 2014. Determining the drivers at the national and sub-

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national levels provides an opportunity to understand the variance at the sub-national level. The findings will inform sub-national specific interventions to promote the reduction of anaemia among WRA.

The drivers associated with a decline in anaemia between 2008 and 2014 at the national and sub-national levels comprised both household and maternal characteristics similar to other studies [21,24,25]. At the national level, the factors included household wealth index and maternal level characteristics (maternal age and education, BMI, and hormonal contraceptive use). At the sub-national level - Eastern Region, the decline in anaemia among WRA was linked to household wealth index, maternal age, maternal educational level, BMI, and hormonal contraceptive use. In the Upper West Region, the key drivers explaining the decline in anaemia prevalence included household access to improve water sources, maternal education, and BMI.

Household wealth index is a measure of the socioeconomic status (SES) of the household, the ability of the household to access basic needs and healthcare services and provide for the needs of household members. It was identified as a driver of the decline in anaemia at the national and the Eastern Region. Over the period of the study, socioeconomic changes [29] were observed in the country. These included an increase in access to information and communication technology (ICT) [30], poverty reduction, improved trade policies, improved healthcare infrastructure (expansion in Community-based Health and Planning Services (CHPS)) [15,31], increasing access to healthcare services; increase in water, sanitation and hygiene (WASH) services (drilling of boreholes and improved toilet facilities) [32,33]; and provision of agricultural inputs and services [34].

Other services were an increase in social safety net programmes such as Livelihood Empowerment Against Poverty (LEAP), the school-feeding programme, health insurance, the distribution of iron-folate supplements to pregnant women and adolescent girls, and provision of Sulfadoxine/pyrimethamine (SP) for presumptive treatment of malaria during pregnancy [35]. These were enabled through government, development partners and individual resources who worked with community leaders to improve the livelihoods of households in the regions [32,36]. All these changes were likely to have influenced household socioeconomic status. According to the 2021 Population and Housing Census [29], the Eastern Region with a wider population experienced more socioeconomic changes and could therefore explain the changes observed as compared to the Upper West Region. Household wealth index was noted to influence a decline in anaemia among WRA in other developing settings [10,25].

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The changes in the SES [20,37] of the country preceding and during the period of study could explain increased access to services including healthcare, and WASH which could have led to better health outcomes such as decline in anaemia noted in this study. For example, there were expansion in access to improved toilet facilities and drilling of boreholes from the activities of non-governmental organisations such as World Vision [38]. These interventions might likely have improved household livelihoods and reduced the risk of infections and sickness which could compromise the nutrition of women as observed by Kothari *et al.* [21]. The evidence of an association between selected WASH indicators and anaemia is well established [10,21,25]. Kothari *et al.* [21] observed that in both WRA and children, the presence of water in the household appeared to be protective against anaemia (lower anaemia prevalence and odds). Nguyen *et al.*, [25] also reported a 9% decline in anaemia prevalence among pregnant women due to improved sanitation in India. Heckert *et al.*, [24] noted a 12% decline in anaemia prevalence among WRA in Tanzania due to a reduction in the percentage of households using open defecation. These studies highlight the benefit of integrating WASH into nutrition interventions specific to addressing anaemia, and therefore suggest an increased access to these services to aid in the reduction of anaemia among WRA.

Hormonal contraceptive use as a driver, reduces the risk of anaemia among WRA possibly through a decrease in monthly menstrual cycle flow and birth spacing [10]. For this study, at the national level, the expansions in healthcare infrastructure [31] and access to healthcare services such as family planning which could have impacted access to hormonal contraceptives by WRA and therefore its uptake, influencing birth spacing. The Eastern Region [39] was observed to have benefited a lot from sexual reproductive health (SRH) services support such as enhanced staff training and women's education on SRH and promotion of free contraceptives from donors and development partners which could explain the use of hormonal contraceptives in the Eastern Region as compared to the Upper West. Hormonal contraceptive use was also noted in other studies to be a driver of anaemia decline among WRA [19,24,40]. Lakew *et al.* [40] from Ethiopia noted that contraceptives use among lactating women was protective against anaemia (-7.7%). Heckert *et al.* [24] study in Tanzania also reported a 30% change in anaemia prevalence a result of contraceptive use.

A higher educational level among WRA as a driver of the decline in anaemia was noted in other studies [24,25]. An increase in education was likely to have led to a better understanding of anaemia and its associated factors among WRA. With an

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increase in the SES of the country and improved ICT, WRA were better positioned to increase their knowledge about anaemia. Increased access to healthcare and possible visits to the health facility and interaction with health staff were likely to have informed dietary choices about the consumption of iron-rich foods, and supplementation, therefore leading to the decline observed. Nguyen *et al.* [25] noted a 24% decline in anaemia among WRA due to improved maternal education. Heckert *et al.*, [24] also noted a 36% change in anaemia among WRA as a result of improved maternal education.

Increased maternal age was a driver of reduced anaemia among WRA. Exposure to activities, projects and interventions as the woman ages were likely to have enhanced the woman's knowledge about anaemia and empowered her to make informed decisions about her dietary habits, and other issues such as family planning and birth spacing. This is consistent with literature [10].

Body mass index was a driver of reduced anaemia at the national and sub-national levels. Women who were normal or overweight/ obese had reduced anaemia compared to underweight women. With improvement in the SES of the country (ICT, reduced poverty), these could have informed dietary habits and patterns and was likely to have led to a decline in anaemia. The findings from this study are similar to those from other studies [14,15,35].

The findings of this study demonstrate the roles of nutrition actions and interventions (nutrition-specific and nutrition-sensitive) in addressing anaemia among WRA. The evidence shows addressing the burden of anaemia among WRA requires multiple actions across different sectors [10]. It also shows evidence of actions and initiatives of the Government of Ghana and development partners that precede the decade under investigation to help explain the observed decline in anaemia among WRA. For example, the development and publication of the National Plan of Action on Food and Nutrition 1995-2002 by the Government of Ghana to address malnutrition served several ministries aside from health (nutrition).

The current study had some limitations. The study used secondary data from cross-sectional studies for analysis. Data for cross-sectional studies are carried out at a single time point and are subject to respondent recall bias therefore it is challenging to establish causality as the outcome and exposure variables are measured at the same time. Secondly, the secondary data did not include variables such as haemoglobin measurement of pregnant women at registration and delivery, and malaria intermittent preventive treatment (IPT) doses which are important indicators about anaemia among WRA to inform decision-making and planning of interventions. And, therefore, recommend the collection of these data in future surveys. Thirdly, the current study used data from the last DHS -2014 in the decomposition analysis to determine the drivers of the decline. It is likely, there have been changes in the explanatory variables up to date which might help explain the decline or otherwise. Despite these limitations, to the best of our knowledge, this study is the first of its kind to examine, identify and describe the drivers of anaemia reduction among WRA at the national and sub-national levels in Ghana. The use of a large nationally representative dataset increased the study sample size and power. The use of the multivariate decomposition technique, a rigorous method enabled the determination of the effect of explanatory variables contributing to the decline observed.

CONCLUSION

The current study provides evidence about the drivers of reduced anaemia prevalence at the national and sub-national levels in Ghana. The decomposition analysis identified changes at the national level in household wealth index, maternal age and education, BMI, and hormonal contraceptive use as key drivers of change. At the sub-national levels - Eastern Region, household wealth index, maternal age and education, BMI, and the use of hormonal contraceptives were the drivers. In the Upper West Region, household access to improved water sources, maternal education, and BMI were the noted drivers. The observed changes in decline in anaemia prevalence could be attributed to improvement in the SES of Ghana and policy and programme interventions such as LEAP, school feeding, and health insurance. Other interventions are WASH, iron-folate supplementation for pregnant and adolescent girls and food fortification. Working engagement across the different sectors from the national to the sub-national level between government and development partners implementing these interventions was also a contributory factor. Further declines in anaemia reduction require more multisectoral coordination and targeted interventions which address the drivers of anaemia among WRA reduction. Identifying the drivers of anaemia reduction among WRA at the national and sub-national levels has highlighted the context-specific drivers needed to tackling anaemia prevalence. It provides an opportunity to understand the variance at the sub-national level which may inform sub-national specific interventions to promote the reduction of anaemia among WRA.

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Ethical approval

The protocol for biomarker data (haemoglobin) testing was approved by the Ghana Health Service Ethical Review Committee in Accra and the ORC Macro Institutional Review Board in Calverton, Maryland, USA [9,10,17].

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Table 1: Multivariate decomposition showing contributions to the reduction in maternal anaemia attributed to differences in endowments and differences in coefficients at the national level, Ghana DHS 2008, and 2014

	Endowment		Coefficient	
	Coefficent	Percent	Coefficent	Percent
Wealth index				
Poorest	-0.00031	0.19	-0.0045	2.77
Poorer	-0.00056**	0.34	0.00613	-3.76
Middle	0.0002	-0.12	0.00657	-4.04
Richer	0.00031*	-0.19	-0.00893	5.49
Richest	-0.00001	0.01	0.00023	-0.14
Maternal current age (years)				
Under 18	-0.00084**	0.52	0.00119	-0.73
18-34	0.00014	-0.09	0.00233	-1.43
35+	-0.00074*	0.45	-0.00432	2.65
Maternal education				
No education	-0.00064	0.39	0.00289	-1.77
Primary	-0.00036	0.22	-0.00966	5.93
Secondary	0.00008	-0.05	-0.00345	2.12
Higher	-0.00125	0.77	0.00147	-0.9
Hormonal contraceptive use				
Do not use hormonal contraceptive	-0.00121***	0.74	0.02732	-16.78
Use hormonal contraceptive	-0.00124***	0.76	-0.00257	1.58
Body mass index (kg/m^2)				
Underweight	-0.00141*	0.87	0.00175	-1.07
Normal	-0.00227*	1.39	-0.00095	0.58
Overweight	-0.00177*	1.09	-0.00328	2.02
Obese	-0.00277*	1.7	-0.00039	0.24
Overall	-0.01471***	9.04	-0.14806	90.96

P-value notation: ***p<0.001, **p<0.01, *p<0.05; kg/.m^2= Kilogram/ metre-squared

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Appendix 1: Summary of Ghana Demographic and Health Surveys included in this study's analysis

Year	Reference period	Number of households interviewed	Number of women aged 15-49 years interviewed	Eligible women's response rate	Number of respondents with measured anaemia status
2003	1999 - 2003	6251	5,691	95.7	5,278
2008	2004 - 2008	11778	4,916	96.5	4,758
2014	2010 - 2014	11835	9,396	97.3	4,704

Appendix 2: Prevalence of household and selected maternal/individual-levelled characteristics of survey respondents across surveys in 2003, 2008, and 2014

Characteristic	2003 GDHS	2008 GDHS	2014 GDHS	2003 and 2014
	%	%	%	%
Sex of household head				
Female	37.5	39.2	38.4	38.4
Wealth index				
Poorest	17.0	16.0	17.0	16.6
Poorer	16.9	18.2	17.2	17.5
Middle	19.2	20.2	20.9	20.0
Richer	21.9	22.9	22.1	22.3
Richest	25.0	22.8	22.8	23.5
Type of residence				
Rural	52.1	51.8	46.1	50.5
Region				
Eastern	9.9	9.8	8.9	9.6
Upper West	2.6	2.5	2.4	2.5
Household size				
<5 residents	39.3	46.1	48.5	44.4
5-7 residents	40.3	38.6	37.5	38.9
8+ residents	20.4	15.3	14.0	16.7
Household access to improved water source				
Improved	81.9	89.7	92.2	87.7
Household access to improved toilet				
Improved not shared	14.2	12.5	14.4	13.5
Improved shared	62.3	57.0	58.5	59.2
Number of insecticide-treated bednets in household				
No net at all	80.7	46.2	24.9	52.7
1 net	12.3	27.0	23.2	21.1
2 nets	4.1	16.7	26.3	14.8
3+ nets	2.8	10.2	25.6	11.5
Maternal current age (years) [Mean ± SD]	29.1 ± 9.7	28.9 ±8.3	29.9 ± 10.0	29.2 ± 9.4

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Under 18	12.4	12.4	10.6	11.9
18-34	56.3	56.3	55.6	56.1
35+	31.3	31.3	33.8	31.9
Religion				
Christian	77.4	77.6	80.1	78.1
Islam	15.5	15.0	15.4	15.3
Traditional/spiritualist/other	2.6	4.3	2.2	3.2
No religion	4.5	3.2	2.2	3.4
Marital status				
Never married	28.0	32.3	32.1	30.8
Currently married	54.4	45.3	42.2	47.6
Cohabiting	8.3	13.2	15.1	12.0
Previously married*	9.2	9.2	10.6	9.5
Educational level				
None	28.2	21.3	19.5	23.2
Primary	20.1	20.3	18.2	19.7
Secondary	49.3	54.8	56.6	53.4
Tertiary	2.4	3.6	5.8	3.8
Body mass index (kg/m ^{2})				
Underweight	8.8	8.1	5.7	7.8
Normal	63.2	61.4	53.8	60.1
Overweight	16.9	20.7	25.0	20.5
Obese	7.3	9.3	15.4	10.1
Missing	3.7	0.6	0.2	1.6
Parity				
None	31.0	33.4	30.6	31.9
1-4	46.2	47.9	50.1	47.9
5-7	17.1	14.6	15.9	15.8
8+	5.7	4.1	3.3	4.5
Children alive				
None	32.3	34.1	31.2	32.8
1-4	49.8	50.9	53.1	51.1
5-7	15.5	13.1	14.2	14.2
8+	2.3	1.8	1.5	1.9
Maternity status				
Neither breastfeeding nor pregnant	68.5	71.5	70.2	70.1
Breastfeeding	23.9	21.2	22.4	22.4
Pregnant	7.6	7.4	7.3	7.4
Hormonal contraceptive use				
Do not use hormonal contraceptive	91.2	91.4	89.2	90.8
Use hormonal contraceptive	8.8	8.6	10.8	9.2
Health insurance				
No	-	60.0	37.7	51.6

Mean ± SD = standard deviation; GDHS= Ghana Demographic and Health Survey;
Previously married = divorced, widower, separated; kg/.m ^{2} = Kilogram/ metre-squared

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Appendix 3: Maternal anaemia prevalence by selected household/individual-levelled characteristics, Ghana 2003, 2008, and 2014

	2003		2008		2014		2003 and 2014	
	% [95% CI]	P-value	% [95% CI]	P-value	% [95% CI]	P-value	% [95% CI]	P-value
Overall	44.6 [42.8,46.4]		58.7 [56.7,60.7]		42.4 [40.5,44.2]		49.9 [48.7,51.1]	
Sex of household head		0.608		0.066		0.127		0.135
Male	44.3 [42.2,46.4]		60 [57.5,62.5]		43.4 [41.2,45.7]		50.5 [49.1,52]	
Female	45.1 [42.3,48]		56.8 [54,59.5]		40.6 [37.6,43.7]		49 [47.2,50.7]	
Wealth index		<0.001		0.020		<0.001		<0.001
Poorest	53.2 [49.6,56.7]		61 [56.6,65.2]		43.6 [39.6,47.6]		53.9 [51.4,56.3]	
Poorer	45.2 [41.2,49.3]		63.1 [59.3,66.7]		50.5 [46.9,54.1]		54.2 [51.8,56.7]	
Middle	47.1 [43.4,50.9]		59.3 [55.4,63]		45.2 [41.2,49.4]		51.7 [49.4,54.1]	
Richer	40.6 [37.3,43.9]		58 [54.2,61.7]		37.2 [33.2,41.4]		47.2 [44.9,49.5]	
Richest	39.9 [36.6,43.3]		53.9 [49.4,58.4]		37.7 [33.3,42.3]		45 [42.5,47.5]	
Type of residence		0.003		0.001		0.509		<0.001
Urban	41.7 [39.1,44.4]		55.3 [52.3,58.4]		41.8 [39.1,44.5]		47.3 [45.5,49]	
Rural	47.2 [44.8,49.7]		61.9 [59.4,64.4]		43 [40.5,45.6]		52.5 [50.9,54.2]	
Region		<0.001		<0.001		0.038		0.017
Western	38.4 [32.8,44.4]		71.3 [64.5,77.3]		42.6 [38.3,47.1]		51.9 [47.1,56.6]	
Central	38.6 [33.4,44.1]		63.5 [59.3,67.6]		46.7 [40.1,53.5]		51.2 [47.3,55.1]	
Greater Accra	47.1 [43.3,50.9]		50.8 [45.9,55.6]		42.4 [37.1,48]		47.3 [44.5,50.1]	
Volta	48.8 [41.4,56.2]		58.1 [52.1,63.9]		48.7 [43.7,53.7]		52.8 [48.8,56.7]	
Eastern	48.6 [42.6,54.6]		58.5 [51,65.7]		38.9 [33.8,44.3]		50.6 [46.5,54.7]	
Ashanti	46.3 [42.6,49.9]		59.9 [55.8,63.9]		40.5 [36.3,44.8]		50.8 [48.2,53.4]	
Brong Ahafo	33.3 [27,40.4]		57.8 [50,65.3]		36.4 [31.8,41.2]		43.8 [39.2,48.5]	
Northern	48.2 [43.7,52.6]		59.5 [53.4,65.3]		47.5 [41.5,53.6]		53 [49.5,56.5]	
Upper East	51.3 [44.9,57.7]		48.3 [41,55.6]		39.6 [33.8,45.7]		47.6 [43.5,51.8]	
Upper West	48.3 [41.3,55.4]		67.1 [62.5,71.3]		35.6 [30.5,41]		53.2 [48.4,57.9]	
Household size		0.479		<0.001		0.182		0.001
<5 residents	43.9 [41.3,46.5]		55.2 [52.5,57.8]		40.8 [38.1,43.6]		47.9 [46.3,49.5]	
5-7 residents	44.4 [41.8,47]		61.1 [58.2,63.8]		43.4 [40.6,46.3]		51 [49.3,52.8]	
8+ residents	46.3 [43.1,49.5]		63.6 [59.2,67.8]		45 [40.8,49.3]		52.6 [50.2,55.1]	

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Household access to improved water source		<0.001		0.080		0.472		0.004
Improved	43.3 [41.3,45.3]		58.2 [56.1,60.3]		42.2 [40.2,44.1]		49.4 [48,50.7]	
Not improved	50.6 [47.1,54.2]		63 [57.9,67.9]		44.7 [38.3,51.2]		54.0 [51,57]	
Household access to improved toilet		0.011		0.552		<0.001		<0.001
Improved not shared	42.8 [37.9,47.8]		56.6 [51,62]		44.7 [39.9,49.7]		48.6 [45.5,51.7]	
Improved shared	43.4 [41.2,45.7]		59.2 [56.6,61.7]		39.4 [37,41.8]		48.8 [47.2,50.3]	
Not improved	49.7 [46.6,52.8]		59.9 [56.8,63]		47.6 [44.5,50.7]		53.9 [52,55.9]	
Missing	41.9 [32.5,51.9]		36.1 [27.2,46]		46.1 [9.53,87.4]		39.7 [33,46.9]	
Number of insecticide-treated bednets in household		0.237		0.101		0.180		<0.001
No net at all	44 [42.1,45.9]		57.3 [54.6,60]		38.8 [34.8,43]		48.2 [46.6,49.8]	
1 net	47.5 [43.4,51.7]		60.3 [57.1,63.4]		43.3 [39.7,46.9]		53.2 [50.9,55.4]	
2 nets	49.4 [41.7,57]		61.8 [57.9,65.5]		43.6 [40.1,47.2]		52.7 [50,55.3]	
3+ nets	43.3 [34.8,52.3]		56 [50.9,60.9]		43.7 [40.4,47]		48.2 [45.5,50.9]	
Maternal current age (years)		0.613		0.001		<0.001		<0.001
Under 18	45.2 [40.9,49.5]		66.4 [62.1,70.5]		53.5 [48.3,58.6]		56.1 [53.3,58.9]	
18-34	44 [41.7,46.2]		57.6 [55.1,60]		41.5 [39.1,43.9]		49 [47.6,50.5]	
35+	45.5 [42.8,48.2]		57.8 [54.8,60.7]		40.3 [37.4,43.3]		49.2 [47.4,50.9]	
Religion		0.002				0.194		0.001
Christian	43.4 [41.3,45.5]		57.9 [55.6,60.2]		41.8 [39.7,44]		49 [47.6,50.4]	
Islam	47.1 [43.8,50.4]		62.3 [57.6,66.9]		42.9 [39.1,46.9]		52.3 [49.7,54.9]	
Traditional/ spiritualist/ other	55.5 [47.5,63.3]		57.5 [51.3,63.4]		51.7 [41.5,61.8]		56 [51.6,60.3]	
No religion	50.6 [44.3,57]		62.9 [54.8,70.4]		47.8 [37.8,58]		55 [50.4,59.5]	
Educational level		0.007		<0.001		0.007		<0.001
None	48.4 [45.9,50.9]		59.9 [56.2,63.4]		45.5 [42.2,49]		52.2 [50.3,54.1]	
Primary	44.3 [40.9,47.7]		63.5 [59.9,67]		44.6 [40.5,48.8]		52.6 [50.3,54.9]	
Secondary	42.9 [40.4,45.4]		57.6 [55,60.1]		41.6 [39.4,43.8]		48.8 [47.3,50.4]	
Tertiary	37.8 [28.9,47.6]		42.9 [32.9,53.5]		32.1 [24.9,40.3]		37.7 [32.3,43.4]	
BMI (kg/m ^{2})		<0.001		<0.001				<0.001
Underweight	47.6 [42.8,52.4]		63.5 [58.2,68.5]		51 [44.2,57.8]		55.1 [51.8,58.3]	

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Normal	47.1 [45,49.2]		61 [58.8,63.2]		46.2 [43.9,48.6]		52.8 [51.4,54.2]	
Overweight	38.7 [35,42.4]		53.3 [49.7,57]		36.5 [32.8,40.4]		44.2 [41.9,46.5]	
Obese	34.9 [29.4,40.9]		51 [45.4,56.5]		35.2 [30.5,40.1]		41.1 [38,44.3]	
Missing	41.2 [35.3,47.3]		70.4 [51.4,84.2]		36.9 [14.9,66.2]		45.6 [39.7,51.5]	
Parity		0.660		0.620		0.169		0.390
None	43.8 [40.8,46.9]		58.7[55.8,61.5]		45 [41.7,48.4]		50.6 [48.7,52.4]	
1-4	44.3 [42,46.6]		58 [55.3,60.6]		40.8 [38.3,43.4]		49.1 [47.5,50.7]	
5-7	46.6 [42.8,50.5]		60.7[56.5,64.7]		41.4 [37.1,45.7]		50.7 [48.3,53.1]	
8+	45.1 [39,51.3]		61.2[53.7,68.1]		46 [36.9,55.3]		51.4 [47.1,55.7]	
Children alive	0.871			0.153		0.127		0.223
None	43.8 [40.9,46.8]		58.5[55.6,61.3]		44.9 [41.5,48.3]		50.4 [48.6,52.3]	
1-4	44.7 [42.5,47]		58.3 [55.7,61]		40.4 [38,42.9]		49.3 [47.7,50.8]	
5-7	45.4 [41.3,49.5]		59.2[54.9,63.4]		44 [39.7,48.3]		50.3 [47.8,52.9]	
8+	47 [37,57.4]		71.4 [61,80]		42.4 [29.5,56.5]		55.9 [49.2,62.5]	
Maternity status		<0.001		<0.001		0.166		<0.001
Neither breastfeeding nor pregnant	41.6 [39.4,43.8]		56.6[54.4,58.9]		41.3 [39,43.6]		47.9 [46.5,49.3]	
Breastfeeding	48 [45.1,51]		61.8[58.4,65.1]		45 [41.4,48.7]		52.7 [50.7,54.7]	
Pregnant	61.1 [55.7,66.2]		70.2[64.7,75.2]		44.6 [38.4,51]		60.8 [57.4,64.2]	
Hormonal contraceptive use		<0.001		0.022		<0.001		<0.001
Do not use hormonal contraceptive	46.1 [44.2,47.9]		59.3[57.3,61.3]		43.6 [41.7,45.6]		51 [49.8,52.2]	
Use hormonal contraceptive	29.4 [25,34.2]		52.8[47.1,58.4]		32.2 [27.9,37]		39.3 [36.3,42.4]	
Health insurance				0.059		0.465		<0.001
No	-		60 [57.5,62.4]		43.2 [40.3,46.1]		55.5 [53.4,57.5]	
Yes	-		56.8 [53.9,59.5]		41.9 [39.6,44.1]		49.6 [47.7,51.5]	

MA = maternal anaemia; P-value notation: ***p<0.001, **p<0.01, *p<0.05., Other = other ethnic groups; Previously married = divorced, widower, separated; BMI = Body mass index; (kg/m^2) = kilogram/metre-squared

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Appendix 4: Estimate of changes in prevalence of selected variables associated with maternal anaemia between surveys, Ghana 2003, 2008, and 2014

	Percent of change/ differences between surveys		
	2003 and 2008	2008 and 2014	2003 and 2014
Wealth index			
Poorest	7.8	-17.4	-9.6
Poorer	17.9	-12.6	5.3
Middle	12.2	-14.1	-1.9
Richer	17.4	-20.8	-3.4
Richest	14	-16.2	-2.2
Household access to improved water source			
Improved	14.9	-16	-1.1
Not improved	12.4	-18.3	-5.9
Number of insecticide-treated bednets in household			
No net at all	13.3	-18.5	-5.2
1 net	12.8	-17	-4.2
2 nets	12.4	-18.2	-5.8
3+ nets	12.7	-12.3	0.4
Maternal current age (years)			
Under 18	21.2	-12.9	8.3
18-34	13.6	-16.1	-2.5
35+	12.3	-17.5	-5.2
Educational level			
None	11.5	-14.4	-2.9
Primary	19.2	-18.9	0.3
Secondary	14.7	-16.0	-1.3
Tertiary	5.1	-10.8	-5.7
Body Mass Index (kg/m ^{2})			
Underweight	15.9	-12.5	3.4
Normal	13.9	-14.8	-0.9
Overweight	14.6	-16.8	-2.2
Obese	16.1	-15.8	0.3
Missing	29.2	-33.5	-4.3
Parity			
None	14.9	-13.7	1.2
1-4	13.7	-17.2	-3.5
5-7	14.1	-19.3	-5.2
8+	16.1	-15.2	0.9
Children alive			
None	14.7	-13.6	1.1
1-4	13.6	-17.9	-4.3
5-7	13.8	-15.2	-1.4
8+	24.4	-29.0	-4.6
Hormonal Contraceptive use			

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Do not use hormonal contraceptive	13.2	-15.7	-2.5
Use hormonal contraceptive	23.4	-20.6	2.8

Other = other ethnic groups; Previously married = divorced, widower, separated; (kg/m^2 = kilogram/metre-squared

Appendix 5: Multivariate decomposition showing contributions to the decline in maternal anaemia attributed to differences in endowments and differences in coefficients for the Eastern region GDHS 2008, and 2014

	Endowment		Coefficient	
	Coefficient	Percent	Coefficient	Percent
Wealth index				
Poorest	-0.00003	0.02	-0.01156	5.95
Poorer	-0.00029*	0.15	0.02827	-14.55
Middle	-0.0003	0.16	-0.00569	2.93
Richer	0.00052	-0.27	-0.01998	10.28
Richest	-0.00091	0.47	0.01223	-6.3
Maternal current age (years)				
Under 18	-0.00013	0.07	-0.0185	9.52
18-34	-0.00004	0.02	0.01827	-9.4
35+	-0.00002	0.01	0.03197	-16.45
Maternal educational level				
No education	-0.00025	0.13	0.00568	-2.92
Primary	-0.00086	0.44	0.02238	-11.52
Secondary	0.00004	-0.02	0.0711	-36.58
Higher	-0.00291	1.5	-0.00743	3.82
Hormonal contraceptive use				
Do not use hormonal contraceptive	-0.00192*	0.99	0.0639	-32.88
Use hormonal contraceptive	-0.002*	1.03	-0.00542	2.79
Body mass index (kg/m^2)				
Underweight	-0.00041	0.21	-0.00468	2.41
Normal	-0.00043	0.22	0.02511	-12.92
Overweight	0.00052	-0.27	0.00765	-3.94
Obese	-0.00202	1.04	-0.0006	0.31
Overall	-0.01164	5.99	-0.18271***	94.01

P-value notation: ***p<0.001, **p<0.01, *p<0.05; kg/.m^2= Kilogram/ metre-squared

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Appendix 6: Multivariate decomposition showing contributions to the decline in maternal anaemia for the Upper West region, GDHS 2008, and 2014

	Endowment		Coefficient	
	Coefficient	Percent	Coefficient	Percent
Household access to improved water source				
Improved	-0.00171	0.54	0.08379	-26.55
Unimproved	-0.00175	0.55	-0.0016	0.51
Maternal education				
No education	-0.0016	0.51	0.02977	-9.43
Primary	-0.00008*	0.02	-0.00818	2.59
Secondary	-0.00048	0.15	0.02245	-7.11
Higher	-0.00256	0.81	-0.00147	0.47
Body mass index (kg/m^2)				
Underweight	-0.00068	0.21	0.00085	-0.27
Normal	-0.0048	1.52	0.06396	-20.26
Overweight	-0.00128	0.4	0.0094	-2.98
Obese	-0.00225	0.71	-0.005	1.58
Overall	-0.0173*	5.48	-0.29836***	94.52

P-value notation: ***p<0.001, **p<0.01, *p<0.05; kg/.m^2= Kilogram/ metre-squared

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Appendix 7: Multivariate decomposition showing contributions to the decline in haemoglobin concentrations at the national and sub-national level-Eastern and Upper West regions, GDHS 2008, and 2014

Components of decomposition	National	Eastern	Upper West
Mean Hb prediction for 2014	11.968	12.018	12.184
Mean Hb prediction for 2008	11.317	11.375	10.972
The difference in mean Hb prediction (2014-2008)	0.652***	0.643	1.212
Contribution to the difference in the mean Hb prediction due to the endowment effect	0.047***	0.015	0.019
Contribution to the difference in the mean Hb prediction due to coefficient effect	0.592***	0.601	1.149
Due to interaction	0.012	0.028	0.044
Endowment as a percent of total	9.8%	6.1%	6.7%
Discrimination as a percent of total	90.2 %	93.9%	93.3%

Source: Computed by the author from 2008 and 2014 Demographic and Health Survey conducted in Ghana; Note: $R = E + C + I$, ***p< 0.001, **p<0.01, *p<0.05