

BMJ Open Determinants of normal haemoglobin concentration among under-five children in Sub-Saharan Africa: a Positive deviance inquiry using cross-sectional study design

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To cite: Seifu BL, Tesema GA, Tebeje T, *et al.* Determinants of normal haemoglobin concentration among under-five children in Sub-Saharan Africa: a Positive deviance inquiry using cross-sectional study design. *BMJ Open* 2024;**14**:e074477. doi:10.1136/bmjopen-2023-074477

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<https://doi.org/10.1136/bmjopen-2023-074477>).

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Received 12 April 2023
Accepted 11 April 2024



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ABSTRACT

Background Low haemoglobin level in children is linked with short-term and long-term consequences including developmental delay. Globally, over half of the children under the age of five years had low haemoglobin concentration. However, there is limited research on the prevalence and determinants of normal haemoglobin concentration among under-five children in sub-Saharan Africa.

Objective To assess determinants of normal haemoglobin concentration among under-five children in SSA.

Design Cross-sectional study design using a positive deviance approach

Setting 33 SSA countries.

Participants 129 408 children aged 6–59 months

Primary and secondary outcome measures A multilevel Poisson regression model with robust variance was fitted to identify determinants of normal haemoglobin concentration. An adjusted prevalence ratio with a 95% CI was reported to declare the statistical significance.

Result The pooled prevalence of normal haemoglobin concentration among under-five children in SSA was 34.9% (95% CI: 34.6% to 35.1%). High maternal education, middle and rich household wealth, female child, frequent antenatal care visits, non-anaemic mothers, taking anthelmintic drugs and normal nutritional status were associated with increased odds of normal haemoglobin concentration. On the other hand, higher birth order, having fever and diarrhoea, rural residence were associated with lower odds of normal haemoglobin levels.

Conclusion According to our finding, only four out of 10 under-five children in SSA had a normal haemoglobin level. This finding proved that anaemia among children in SSA remains a serious public health concern. Therefore, improving maternal education, provision of drugs for an intestinal parasite and early detection and treatment of maternal anaemia, febrile illness and diarrhoeal disease is important.

STRENGTHS AND LIMITATIONS OF THE STUDY

- ⇒ This study was based on a pooled nationally representative Demographic and Health Survey (DHS) of the 33 sub-Saharan African countries, which made the observed associations more robust and enhanced the generalisability of the findings.
- ⇒ The haemoglobin concentration was objectively measured, which helps to reduce potential misclassification.
- ⇒ We are unable to draw cause-and-effect relationships because of the cross-sectional nature of DHS data.
- ⇒ Because these variables were not available in DHS, we did not consider important predictors such as visceral leishmaniasis, hookworm and congenital infections.

BACKGROUND

The world Health Organisation (WHO) defines anaemia among under-five children as a haemoglobin (Hb) concentration below 11 g/dL.¹ Anaemia is a medical disorder that is defined by a deficiency in the amount of healthy red blood cells, which frequently coincides with decreased haemoglobin levels or abnormal shape of blood cells, preventing blood from providing oxygen to the tissues of the body.^{2,3}

Anaemia is a major public health concern around the world, primarily affecting young children and pregnant women.^{4,5} According to the WHO, an estimated 269 million under-five children worldwide are anaemic, with a prevalence of 39.8%.⁶ The African region has the highest prevalence of anaemia among children under the age of five, with 60.2%.⁷

The most common causes of anaemia in children are haemoglobinopathies, dietary deficiencies (such as iron, folate, vitamins

B₁₂ and A) and infectious illnesses such as malaria, tuberculosis, HIV and hookworm.^{8–10} Anaemia has serious short-term and long-term consequences for children's health. It harms children's health by causing developmental delays, lower cognitive development, low immunity, weariness, difficulties to focus, lethargy, increased mortality and infection susceptibility.¹¹ Furthermore, anaemia in childhood is linked to a decrease in ability to combat illnesses, which leads to substantial morbidity and death in children.¹²

Given the consequences, effective and efficient public health strategies to address childhood anaemia are urgently needed. In order to design effective interventions, it is critical to have a clear understanding about the factors that have the potential to prevent children from developing anaemia. The current study aims to shed light on these factors by focusing on children with normal Hb concentrations (ie, children who do not have any form of anaemia). The study will provide a comprehensive understanding of the factors that promote normal Hb concentration as opposed to the risk factors for low Hb concentration (anaemia). Indeed, understanding the factors that contribute for normal Hb concentration in children, which is currently lacking in sub-Saharan Africa (SSA), is critical for developing effective anaemia prevention programmes.

The analytical strategy of the present study was positive deviance (PD), a resource-based approach. The concept of PD is preceded by the statement that 'in every community there are some individuals or groups whose unusual behaviors and strategies enable them to find better solutions to problems than their peers, despite having access to the same resources and facing similar or worse challenges'.^{13 14} The PD concept aims to study the behaviours and characteristics of those who achieve better results on a given health outcome than their peers who reside in the same community.¹⁵ It is an established concept that can be studied using a statistical approach and is often quantified as those who do not experience a negative outcome of interest compared with their peers in the same settings.¹⁵ In the past, the PD method was used to investigate neonatal care, childhood anaemia, child nutrition, safe sex practices, malaria control, health service delivery and educational outcomes in a variety of settings.^{16–19} Indeed, almost all of these PD studies were conducted outside SSA except a study conducted in Ghana.²⁰ In SSA countries, the application of PD in investigating child health outcomes is relatively rare. This suggests the need for more research using the PD approach in SSA.

The PD approach is unique in that it focuses on the 'positive' aspects of an outcome rather than the 'negative' and it can identify potential points of intervention. Positive deviants in the current study were children who lived in anemia-endemic SSA countries but had normal Hb concentrations (not anaemic) compared with their counterparts who lived in the same countries but were anaemic. The primary goal of this study is to investigate the factors that influence normal Hb concentration among

children living in SSA countries. Identifying these determinants would serve as the foundation for developing programmes aimed at children in SSA countries who are at risk of having low Hb concentrations. It is important to note that the current study's resource-focused approach differs from the dominant risk model approach, in which the focus is typically on children with poor health and the associated risk factors.

METHODS

Data source and sampling procedure

This study was based on the most recent Demographic and Health Survey (DHS) of 33 SSA countries. The DHS is conducted every 5 years to generate updated health and health-related indicators. The study subjects were chosen using a two-stage stratified sampling technique. Enumeration areas were chosen at random in the first stage, and households were chosen in the second. Children in the chosen households underwent haemoglobin testing using the HemoCue rapid testing methodology to determine their anaemia status. A drop of capillary blood was drawn from the kids' fingertip or heel for the test, and the haemoglobin concentration was measured using a photometer. DHS has a variety of data sets, and we used the Kids Record (KR) file for this study. Based on reviewed literatures, we extracted the data from the KR data set and then appended it using the STATA command 'append using'. Combining separate data sets from each SSA country into a single data set through the process of data set appending is a common practice in data analysis. By doing so, we create a unified data set that allows for more efficient management and analysis within STATA. This study's final sample size was 129 408 children aged 6–59 months (table 1). Detailed information about DHS methodology can be found from the official database <https://dhsprogram.com/Methodology/index.cfm>.

Study variables and measurements

Dependent variable

The response variable was Hb concentration of children. The Hb data were categorised into mild anaemia (haemoglobin level 10.0–10.9 g/dL), moderate anaemia (haemoglobin level 7.0–9.9 g/dL), severe anaemia (haemoglobin level <7.0 g/dL) and no anaemia (hemoglobin ≥11.0 g/dL).²¹ In this study, mild, moderate and severe anaemia were recoded as 'anaemic or low Hb concentration' and assigned a value of '0' (referenced category), while children who did not have any form of anaemia were assigned a value of '1' (non-anaemic or normal Hb concentration) (outcome of interest). Because PD is the analytic lens, children with normal Hb concentrations were classified as positive deviants.

Independent variables

Given the hierarchical structure of the DHS data, where mothers and children were nested within the cluster, and in accordance with the study's objectives, two levels of

Table 1 The prevalence of mild, moderate and severe anaemia (along with normal haemoglobin) across the 33 countries studied

Country	Year of survey	Severe anaemia (%)	Mild anaemia (%)	Moderate anaemia (%)	No anaemia (%)
Angola	2015–2016	2.12	30.00	32.00	35.88
Burkina Faso	2021	10.91	18.47	58.94	11.68
Benin	2017–2018	3.39	27.76	40.57	28.28
Burundi	2016–2017	3.29	24.59	30.99	41.13
Congo Dr	2013–2014	3.74	24.72	34.53	37.01
Congo	2011–2012	1.24	31.49	33.48	33.79
Cote d'Ivoire	2021	3.53	24.95	46.92	24.60
Cameroon	2018	2.01	25.50	29.92	42.57
Ethiopia	2016	4.00	23.79	32.58	39.63
Gabon	2019–2021	1.77	29.40	32.47	36.36
Ghana	2014	2.98	27.30	39.49	30.23
Gambia	2019–2020	1.83	24.70	26.70	46.77
Guinea	2018	2.10	29.50	42.00	26.40
Liberia	2019–2020	2.40	28.10	40.10	29.40
Lesotho	2014	1.74	25.08	26.20	46.98
Madagascar	2021	0.55	26.26	20.77	52.42
Mali	2018	5.14	24.52	50.41	19.93
Mauritania	2019–2021	8.40	20.01	46.08	25.51
Malawi	2015–2016	1.75	26.88	34.00	37.07
Mozambique	2011	3.37	26.24	36.67	33.72
Nigeria	2018	3.16	27.26	38.57	31.36
Niger	2012	2.82	26.58	45.06	25.44
Namibia	2013	0.98	24.60	25.00	49.42
Rwanda	2019–2020	0.29	21.30	14.90	63.51
Sierra Leone	2019	3.16	30.51	36.27	30.06
Sao tome and Principe	2008–2009	1.04	31.10	27.06	40.80
Swaziland	2009	1.10	22.94	20.99	54.97
Togo	2013–2014	2.63	25.90	42.34	29.13
Tanzania	2022	1.53	27.25	29.70	41.52
Uganda	2016	2.28	24.44	27.84	45.54
South Africa	2016	2.75	25.99	32.89	38.37
Zambia	2018	1.43	28.54	28.00	42.03
Zimbabwe	2015	0.51	22.21	15.50	61.78

independent variables were taken into consideration. The attributes related to households, maternal factors and child-related traits were categorised as individual-level factors. Household-related factors included household wealth index, family size, the gender of the household head and media exposure. Maternal age, maternal education, marital status, maternal anaemia, the number of antenatal care (ANC) visits during pregnancy and the place of delivery were all maternal-related factors. The following child-related factors are included: a child's age, size at birth, sex, type of birth, birth order, diarrhoea or fever within the previous 2 weeks, and use of an intestinal parasite medication within the previous 6 months.

Stunting status (Z-scores for height for age (HAZ)), wasting status (Z-scores for weight-for-height (WHZ)) and underweight status (WAZ)). Children who are stunted are those whose height-for-age Z-score (HAZ) is less than two SD, wasted are those whose weight-for-height Z-score (WHZ) is less than two SDs and underweight are those whose weight-for-age Z-score (WAZ) is less than two SDs. The SSA region and residence were community-level variables.

Data management and analysis

Data extraction, coding and analysis were done using Stata V.17 statistical software. To make the data more

representative again, analysis was done using the weighted data. The intra-class correlation coefficient (ICC) was estimated to evaluate the clustering effect because the DHS data are hierarchical in nature. There was a sizeable clustering effect, according to the ICC (ICC>10%). This study was a cross-sectional study and the prevalence of not anaemic (positive deviant) was greater than 10%, and if we report the OR, it could overestimate the association between anaemia status and the independent variables. The best measure of association in these situations is the prevalence ratio, so multilevel Poisson regression analysis with robust variance was fitted to find predictors of not being anaemic (normal Hb concentration). In the bivariable multilevel Poisson regression analysis, variables with a p-value of <0.2 were taken into account for the multivariable analysis.

Four models were constructed for the multilevel Poisson regression analysis. The first model was a null model without explanatory variables to determine the extent of cluster variation in childhood normal Hb concentration. The second model was fitted with individual-level variables, the third with community-level variables and the fourth with both individual and community-level variables at the same time. The deviance (-2Log-likelihood ratio) was used to compare the nested models, and the model that had the lowest deviance was the one that best fit the data. The adjusted prevalence ratio (APR) and its 95% CI were then reported, and variables with a p<0.05 in the multivariable analysis were regarded as significant predictors of normal Hb concentration in children under the age of five.

Ethical consideration

This study did not require ethical approval or participant consent because it was a secondary data analysis of publicly available survey data from the MEASURE DHS programme. We have obtained permission to download and use the data from <http://www.dhsprogram.com> for this study. There are no names or addresses of individuals or households recorded in the data sets.

Patient and public involvement statement

Patients and public involvement were not involved in this study since we have conducted a secondary data analysis based on already available DHS data, which were collected to provide estimates of common health, and health related indicators.

RESULTS

Descriptive characteristics of the study participants

A total of 129 408 children aged 6–59 months were included in the study. Of these, 87 612 (67.70%) were from rural area. Regarding the SSA region, 23 766 (18.36%), 54 734 (42.30%), 23 645 (18.27%) and 27 262 (21.07%) were from East Africa, West Africa, Southern Africa and Central Africa, respectively. About 59 772 (64.49%) aged 24–59 months and 65 189 (50.38%) were

males. Regarding nutritional status, 46 733 (36.11%), 8116 (6.27%) and 23 052 (17.81%) of the children were stunted, underweight and wasted, respectively (table 2).

The pooled prevalence of normal haemoglobin concentration

The pooled prevalence of normal haemoglobin concentration among children aged 6–59 months in SSA were 34.89% (95% CI: 34.63% to 35.14%), Rwanda 63.53% (95% CI: 61.90% to 65.16%) and Burkina Faso 11.68% (95% CI: 10.83% to 12.53%) had the highest and lowest prevalence, respectively (figure 1).

Individual and community-level determinants of normal haemoglobin concentration

High maternal education, older maternal age, middle and rich household wealth index, being a female child, ANC visit >4, not anaemic mothers, taking drugs for an intestinal parasite, and having normal nutritional status (not stunted and wasted) were significantly associated with increased odds of having a normal Hb concentration. Whereas higher order birth, having fever in the last 2 weeks, having diarrhoea in the last 2 weeks, rural residence, residing in southern and western SSA regions were significantly associated with lower odds of having a normal Hb concentration.

The prevalence of having a normal Hb concentration among female children were 6% (APR=1.06, 95% CI: 1.04 to 1.08) higher than male children. The prevalence of having normal Hb concentration among children whose mother aged 25–34 years, and ≥35 years were increased by 8% (APR=1.08, 95% CI: 1.05 to 1.11) and 19% (APR=1.19, 95% CI: 1.15 to 1.24) compared with children whose mother aged less than 25 years, respectively. Children from middle and rich household wealth had 9% (APR=1.09, 95% CI: 1.05 to 1.12) and 7% (APR=1.07, 95% CI: 1.04 to 1.11) higher prevalence of having normal Hb concentration compared with children from the poor household wealth, respectively. Children who had diarrhoea in the last 2 weeks had decreased prevalence of having normal Hb concentration (APR=0.93, 95% CI: 0.90 to 0.96) compared with their counterparts. The prevalence of having normal Hb concentration among children in Southern and Western Africa were decreased by 19% (APR=0.81, 95% CI: 0.77 to 0.85) and 27% (APR=0.73, 95% CI: 0.70 to 0.77), compared with children in Central Africa, respectively (table 3).

DISCUSSION

Using nationally representative data, this study investigated the determinants of normal Hb concentration among children aged 6–59 months in SSA. Rather than focusing on at-risk or children with poor health outcomes, the analysis focused on children who are doing well (positive deviants).

The pooled prevalence of normal haemoglobin concentration among children aged 6–59 months in SSA were 34.89% (95% CI: 34.63% to 35.14%), Rwanda

Table 2 Descriptive characteristics of children aged 6–59 months in sub-Saharan Africa

Variable	Frequency (N=129 408)	Percentage (%)
Household characteristics		
Household wealth status		
Poor	57 241	44.23
Middle	26 284	20.31
Rich	45 883	35.46
Family size		
2–4	32 386	25.03
4–8	67 999	52.55
>8	29 022	22.43
Sex of household head		
Male	102 528	79.23
Female	26 879	20.77
Media exposure		
No	45 788	35.38
Yes	83 619	64.62
Maternal-related characteristics		
Maternal age		
15–24	34 405	26.59
25–34	63 163	48.81
≥35	31 840	24.60
Maternal education		
No formal education	47 028	36.34
Primary	45 421	35.10
Secondary	32 968	25.48
Higher	3991	3.08
Maternal marital status		
Single	7966	6.16
Married/living together	112 426	86.88
Widowed/divorced/separated	9015	6.97
Maternal anaemia status		
Anaemic	59 883	46.27
Not anaemic	69 524	53.73
Maternal ANC visit		
No	7792	6.02
1–3 visits	28 591	22.09
>4 visits	93 024	71.88
Place of delivery		
Home	40 985	31.67
Health facility	884 223	68.33
Child's characteristics		
Sex of child		
Male	65 189	50.38
Female	64 218	49.62
Age of child (in months)		
6–23	32 916	35.51
24–59	59 772	64.49
Size of child at birth		
Average	66 306	51.27

Continued

Table 2 Continued

Variable	Frequency (N=129 408)	Percentage (%)
Small	19 653	15.20
Large	43 373	33.54
Type of birth		
Single	125 390	96.90
Multiple	4017	3.10
Taking drug for intestinal parasite in the last 6 months		
No	66 476	55.27
Yes	53 809	44.73
Diarrhoea in the last 2 weeks		
No	108 805	84.12
Yes	20 542	15.88
Fever in the last 2 weeks		
No	100 920	78.02
Yes	28 427	21.98
Birth order		
1–3	73 981	57.17
4–6	39 118	30.23
>6	16 309	12.60
Underweight status		
Underweight	8116	6.27
Normal	121 291	93.73
Wasting status		
Wasted	23 052	17.81
Normal	106 354	82.19
Stunting status		
Stunted	46 733	36.11
Normal	82 675	63.89
Community-level variables		
Residence		
Urban	41 796	32.30
Rural	87 612	67.70
Sub-Saharan African region		
Central Africa	27 262	21.07
East Africa	23 766	18.36
South Africa	23 645	18.27
West Africa	54 734	42.30

ANC, antenatal care.

63.53% (95% CI: 61.90% to 65.16%) and Burkina Faso 11.68% (95% CI: 10.83% to 12.53%) had the highest and lowest prevalence, respectively. Rwanda has achieved tremendous success in health and development in recent years. The World Bank confirms that Rwanda's economy has been consistently rising for over a decade, with an impressive annual growth rate of 7.2% from 2007 to 2019.²² Furthermore, Rwanda has made remarkable progress in improving living standards, becoming one of the only two SSA countries to achieve all of the Millennium Development Goals related to health.²³ Rwanda has successfully tackled childhood anaemia by taking a proactive approach to combat infectious diseases, malnutrition

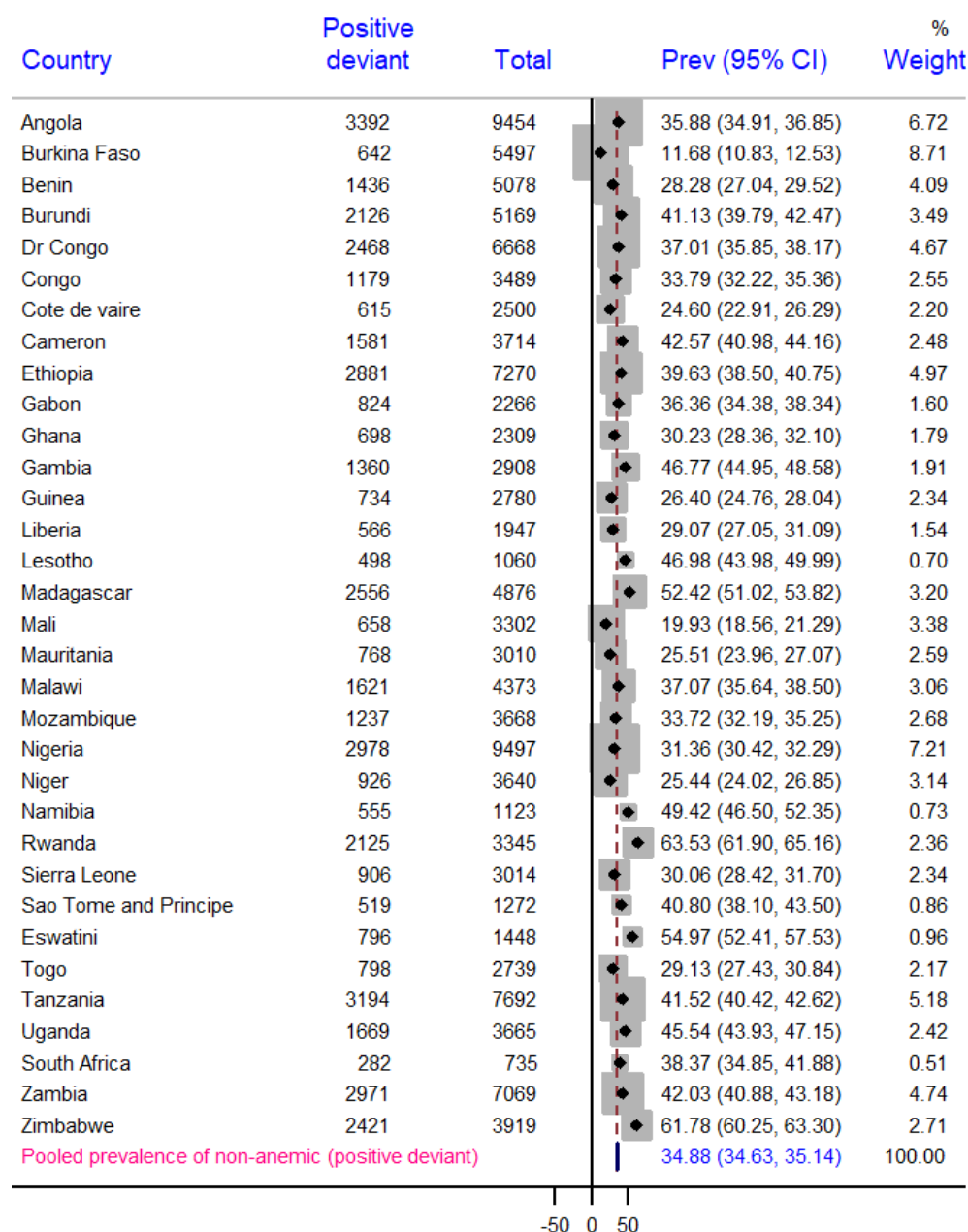


Figure 1 Pooled prevalence of normal haemoglobin concentration among under five children in sub-Saharan Africa.

and poor hygiene and sanitation.²⁴ The aforementioned factors may explain the high prevalence of normal haemoglobin levels among Rwandan children under the age of five.

The following factors were significantly associated with normal Hb concentration in children: child sex, child age, maternal educational status, household wealth status, number of ANC visits, maternal age, having fever in the last 2 weeks, having diarrhoea in the last 2 weeks, residence SSA region, child twin status, birth order and child's nutritional status (stunting and wasting). In line with this study,^{25–27} previous studies revealed that female children were at lower odds of having higher levels of anaemia compared with male children. The possible justification could be due to

too early initiation of complementary feeding for male children than females, which in turn expose them to different infectious diseases and malabsorption problems.^{28 29} Furthermore, male children in their first 2 years of life experience rapid growth, which increases their micronutrient demands, including vitamin B₉, B₁₂ and iron, increasing their risk of anaemia when compared with female children.³⁰

Mothers who have more years of education were more likely to have children with a normal Hb concentration; this might be because of maternal education is a reliable predictor of children's nutritional outcomes.^{31 32} Maternal education helps to improve maternal understanding of child health and nutrition (such as exclusive breastfeeding and

Table 3 Multilevel robust Poisson regression analysis of individual and community-level variables associated with normal Hb concentration among children aged 6–23 months in Sub-Saharan Africa

Variables	Model 1	Model 2	Model 3
	APR with 95% CI	APR with 95% CI	APR with 95% CI
Individual-level variables			
Maternal age			
15–24	1		1
25–34	1.09 (1.06 to 1.12)		1.08 (1.05 to 1.11)*
≥35	1.21 (1.16 to 1.25)		1.19 (1.15 to 1.24)*
Maternal education			
No formal education	1		1
Primary	1.16 (1.13 to 1.19)		1.12 (1.09 to 1.15)*
Secondary	1.15 (1.11 to 1.19)		1.14 (1.10 to 1.18)*
Higher	1.26 (1.19 to 1.33)		1.24 (1.17 to 1.32)*
Household wealth status			
Poor	1		1
Middle	1.10 (1.07 to 1.14)		1.09 (1.06 to 1.13)*
Rich	1.15 (1.12 to 1.18)		1.07 (1.05 to 1.11)*
Family size			
2–4	1		1
4–8	0.97 (0.94 to 0.99)		0.98 (0.95 to 1.00)
>8	0.93 (0.89 to 0.96)		0.97 (0.94 to 1.01)
Maternal anaemia status			
Anaemic	1		1
Not anaemic	1.49 (1.46 to 1.52)		1.45 (1.42 to 1.49)*
Maternal ANC visit			
No	1		1
1–3	1.08 (1.02 to 1.15)		1.06 (0.99 to 1.12)
>4	1.12 (1.06 to 1.18)		1.11 (1.05 to 1.18)*
Media exposure			
No	1		1
Yes	1.00 (0.98 to 1.03)		11.01 (0.99 to 1.04)
Sex of child			
Male	1		1
Female	1.06 (1.04 to 1.08)		1.06 (1.04 to 1.08)*
Age of child (in months)			
6–23	1		1
24–59	1.72 (1.67 to 1.76)		1.72 (1.67 to 1.77)*
Size of child at birth			
Average	1		1
Small	1.02 (0.98 to 1.05)		1.00 (0.97 to 1.03)
Large	0.99 (0.97 to 1.02)		1.00 (0.98 to 1.03)
Type of birth			
Single	1		1
Multiple	0.96 (0.90 to 1.01)		0.96 (0.91 to 1.03)
Taking drug for intestinal parasite in the last 6 months			
No	1		1

Continued

Table 3 Continued

Variables	Model 1	Model 2	Model 3
	APR with 95% CI	APR with 95% CI	APR with 95% CI
Yes	1.08 (1.05 to 1.10)		1.06 (1.04 to 1.08)*
Diarrhoea in the last 2 weeks			
No	1		1
Yes	0.94 (0.91 to 0.97)		0.94 (0.91 to 0.97)*
Fever in the last 2 weeks			
No	1		1
Yes	0.82 (0.79 to 0.84)		0.81 (0.79 to 0.84)*
Birth order			
1–3	1		1
4–6	0.93 (0.91 to 0.96)		0.94 (0.91 to 0.96)*
>6	0.96 (0.92 to 0.99)		0.94 (0.91 to 0.99)*
Underweight status			
Underweight	1		1
Normal	1.02 (0.97 to 1.07)		1.02 (0.97 to 1.07)
Wasting status			
Wasted	1		1
Normal	1.09 (1.05 to 1.13)		1.11 (1.07 to 1.14)*
Stunting status			
Stunted	1		1
Normal	1.15 (1.12 to 1.18)		1.16 (1.13 to 1.19)*
Community-level variables			
Residence			
Urban		1	1
Rural		0.82 (0.81 to 0.84)	0.93 (0.90 to 0.96)*
Sub-Saharan African region			
Central Africa		1	1
East Africa		1.13 (1.09 to 1.16)	0.97 (0.92 to 1.01)
South Africa		1.12 (1.08 to 1.15)	0.81 (0.77 to 0.85)*
West Africa		0.72 (0.44 to 0.46)	0.74 (0.71 to 0.77)*
Random-effect analysis result			
Community-level variance	0.25	0.22	0.20
LR test Prob $\geq$ chibar ² <0.00			
LLR	–45, 897.26	–94, 852.69	–45, 696.74
Deviance	91 794.52	189, 705.38	91, 393.48
AIC	91, 862.52	189, 719.4	91, 471.48
BIC	92, 170.71	189, 787.8	91, 824.98

*P<0.05.

AIC, Akaike Information Criteria; ANC, antenatal care; APR, adjusted prevalence ratio; BIC, Bayesian Information Criteria; Hb, haemoglobin; LLR, log-likelihood ratio; LR, likelihood ratio.

appropriate complementary feeding), which helps to improve the quality of children's diets.³¹ Furthermore, mothers' educational levels can positively influence their children's healthcare and feeding practices.³³ This finding is consistent with previous

studies showing that children with more educated mothers are less likely to develop anaemia than those with less educated mothers.^{20 34 35}

Children of mothers aged 25–34, and >34 years had lower odds of being anaemic compared with children of

a mother aged 15–25 years. This was in agreement with study findings in SSA,³⁵ Haiti,³⁶ Brazil³⁷ and India.³⁸ Extensive research indicates that older mothers are far better equipped to meet their children's healthcare needs. It is evident that children born to younger mothers are at a higher risk of developing anaemia, which underscores the fact that younger mothers are often not prepared to fulfil their children's nutritional requirements and maternal obligations. The reasons for this could include limited financial resources, inadequate knowledge about anaemia and childcare and insufficient guidance.^{37 39 40}

The possibility of having normal Hb concentration was more prevalent among children in households with middle and rich wealth indices had increased odds of having normal levels of Hb concentration compared with those from the poorest households. This is consistent with study findings in SSA,³⁵ Sri Lanka⁴¹ and Bangladesh,⁴² this could be due to parents from the wealthiest households can provide their children with a balanced diet rich in macro and micronutrients, as well as minerals and vitamins.^{43 44} Furthermore, children from wealthy families have a better chance of accessing healthcare for common illnesses that cause childhood anaemia.⁴⁵

According to the findings of this study, mothers who were able to attend at least four ANC visits were more likely to have children with normal haemoglobin levels. This could be because pregnant mothers benefit from iron-folate supplementation as well as prompt diagnosis and treatment of diseases such as malaria, visceral leishmaniasis and hookworm, which have been identified as leading causes of anaemia, which in turn reduces the risk of child anaemia.⁴⁶ A strong relationship between maternal anaemia and child haemoglobin concentration was observed in this study. Non-anaemic mothers have children with normal haemoglobin concentrations. Thus, whether or not a child has a normal Hb concentration is dependent on the mother's anaemia status. This could be because children's primary source of nutrition is their mother, also because the children eat a similar diet, it is possible that their eating practices and quality of life are the same.⁴⁷ Furthermore, non-anaemic mothers' breast milk may contain sufficient iron, zinc, folate and vitamin B₁₂, resulting in a normal Hb concentration in the child.⁴⁸

In this study, children who have two or more older siblings in the household were found to have lower odds of having a normal Hb concentration. It is congruent with the findings of studies in SSA³⁴ and Central India.⁴⁹ The possible explanation could be that increasing birth order is associated with a depletion of nutrients such as iron, folate, and vitamin B₉ in the mother, which could result anaemia in children.⁵⁰

Consistent with studies done in SSA³⁴ and Indonesia,⁵¹ in this study, children who had a fever and diarrhoea in the last 2 weeks had higher odds of higher levels of anaemia compared with their counterparts. This could be because children with febrile and diarrhoeal illnesses may experience a loss of appetite as well as decreased absorption of essential nutrients (iron, folate and vitamin B₁₂),

which may increase the likelihood of anaemia (low Hb concentration).⁵²

In this study, children who were not stunted or wasted had a higher chance of having normal Hb concentrations than stunted and wasted children. Low immunity is related to poor nutritional status, in addition to deprivation of nutrients required for hematopoiesis. Therefore, diseases and infestations cause anaemia by a synergistic effect of nutritional deficits.⁵³ Furthermore, well-fed children are less likely to suffer from micronutrient deficiencies, such as iron, vitamin A, vitamin B₁₂ and folic acid, which aid in haemoglobin and DNA synthesis during red blood cell production.⁵³

Consistent with studies done in SSA³⁴ and Thailand,⁵⁴ children who had taken intestinal parasite drugs in the previous 6 months had a higher chance of having a normal Hb concentration than children who had not taken intestinal parasite drugs. This could be because intestinal parasites can cause anaemia, and thus drugs for intestinal parasites can reduce the risk of anaemia in children.⁵⁵

The implications of these findings are that there are several factors that can influence the haemoglobin concentration of children in SSA. Addressing these factors could have a positive impact on the health outcomes of children in the region. For instance, interventions aimed at enhancing maternal education, household income and access to health services could improve the nutritional status of children and reduce the incidence of anaemia. Additionally, interventions targeting infectious diseases, such as intestinal parasites, could help to mitigate the prevalence of anaemia. By prioritising these interventions, stakeholders and policymakers can make a significant contribution to improving the health and well-being of children in SSA.

When interpreting our study's findings, keep the following limitations in mind. Owing to the cross-sectional design of the DHS data, it is imperative to note that establishing cause-and-effect relationships is unfeasible. It is important to highlight that the DHS data set did not include crucial factors such as malaria infection, visceral leishmaniasis, hookworm and congenital illnesses, and thus it was not possible to assess their impact.

CONCLUSION

This study tries to provide a thorough understanding of the factors that promote normal Hb concentration rather than the risk factors for low Hb concentration (anaemia) among children aged 6–23 months in sub-Saharan Africa. Both individual and community-level variables were found significant predictors of normal Hb concentration among children aged 6–23 months. Child age, child sex, size at birth, maternal education, maternal age, fever in the last 2 weeks, birth order and household wealth status were among individual-level predictors of normal Hb concentration among children aged 6–23 months. Among community-level variables, SSA regions and

residence were found significant predictors of normal Hb concentration.

According to the study's findings, mothers with more years of education were more likely to have children with normal Hb concentrations. This suggests that maternal education may be able to protect children from anaemia. There was a strong relationship between ANC visits and child Hb concentrations. Therefore, promoting ANC attendance among women of reproductive age will have the potential to protect their children from developing anaemia in the first 5 years of their life. Furthermore, providing treatment for febrile illness and strengthening the economic status of the family could contribute for the better reduction in the risk of anaemia and improvements in haemoglobin levels among children. Furthermore, in order to reduce child anaemia, it is preferable to strengthen early detection and management strategies for stunted, wasted and underweight children.

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Acknowledgements We would like to thank the measure DHS programme for providing the data sets.

Contributors Data curation and software: BLS, GAT and KU. Conceptualisation, formal analysis and methodology: BLS and GAT. Investigation: BLS, GAT, TMT, BTL, TZY, AGW and KU. Validation, writing—original draft, writing—review and editing and visualisation: BLS, GAT, TMT, BTL, TZY, AGW, ZBT and KU. Guarantor: BLS

Funding The authors have not declared a specific grant for this research from any funding agency in the public, commercial or not-for-profit sectors.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval This study did not require ethical approval or participant consent because it was a secondary data analysis of publicly available survey data from the MEASURE DHS programme. We have obtained permission to download and use the data from <http://www.dhsprogram.com> for this study. There are no names or addresses of individuals or households recorded in the data sets.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available in a public, open access repository. All the data files are available from the measure. DHS programme data are available online and you can access it from www.measuredhs.com.

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REFERENCES

- Patel KV. Epidemiology of anemia in older adults. *Seminars in Hematology* 2008;45:210–7.
- Amy R. Koehn PDNNPBC. Neonatal nurse practitioner certification intensive review: fast facts and practice questions. Springer Publishing Company; 2019. Available: <https://books.google.com.et/books?id=d3KIDwAAQBAJ>
- Bishlawy IM. Red blood cells, hemoglobin and the immune system. *Med Hypotheses* 1999;53:345–6.
- Milman N. Still a major health problem in many parts of the world. *Ann Hematol* 2011;90:369–77.
- Stevens GA, Finucane MM, De-Regil LM, et al. Global, regional, and national trends in Haemoglobin concentration and prevalence of total and severe anaemia in children and pregnant and non-pregnant women for 1995–2011: a systematic analysis of population-representative data. *The Lancet Global Health* 2013;1:e16–25.
- WHO. *Global Anaemia Estimates*. 2021:1–6. Available: https://www.who.int/data/gho/data/themes/topics/anaemia_in_women_and_children
- World Health Organization. Prevalence of anemia among children under 5 years. Who; 2022. Available: <https://www.who.int/data/gho/indicator-metadata-registry/imr-details/4801>
- Chaparro CM, Suchdev PS. Anemia epidemiology, pathophysiology, and etiology in Low- and Middle-Income countries. *Annals of the New York Academy of Sciences* 2019;1450:15–31.
- Jonker FAM, Boele van Hensbroek M. Anaemia, iron deficiency and susceptibility to infections. *J Infect* 2014;69 Suppl 1:S23–7.
- Dreyfuss ML, Stoltzfus RJ, Shrestha JB, et al. Hookworms, malaria and vitamin A deficiency contribute to anemia and iron deficiency among pregnant women in the plains of Nepal. *J Nutr* 2000;130:2527–36.
- Abu-Ouf NM, Jan MM. The impact of maternal iron deficiency and iron deficiency anemia on child's health. *Saudi Med J* 2015;36:146–9.
- Brabin BJ, Premji Z, Verhoeff F. An analysis of anemia and child mortality. *The Journal of Nutrition* 2001;131:636S–648S.
- Sternin M, Sternin J, Di M. Rapid sustained childhood malnutrition alleviation through a positive-deviance approach in rural Vietnam: preliminary findings. 1997.
- Zeitlin MF, Ghassemi H, Mansour M, et al. Positive deviance in child nutrition: with emphasis on Psychosocial and behavioural aspects and implications for development / by Marian Zeitlin, Hossein Ghassemi, and Mohamed Mansour; with the collaboration of Robert A. Levine. In: United Nations University Press. Published with the support of the WHO/UNICEF Joint, 1990.
- Long KN, Gren LH, Rees CA, et al. Determinants of better health: a cross-sectional assessment of positive deviants among women in West Bengal. *BMC Public Health* 2013;13:372.
- Baxter R, Taylor NJ, Kellar I, et al. What methods are used to apply positive deviance within Healthcare organisations? A systematic review. *BMJ Qual Saf* 2016;25:190–201.
- Shafique M, Edwards HM, De Beyl CZ, et al. Positive deviance as a novel tool in malaria control and elimination: methodology, qualitative assessment and future potential. *Malar J* 2016;15:91.
- Ruiz-Peláez JG, Charpak N, Cuervo LG. Kangaroo mother care, an example to follow from developing countries. *BMJ Br Med J* 2004;329:1179–81.
- Bolles K, Speraw C, Berggren G, et al. Ti foyer (hearth) community-based nutrition activities informed by the positive deviance approach in Leogane, Haiti: a programmatic description. *Food Nutr Bull* 2002;23:11–7.
- Amugsi DA. n.d. Determinants of normal Haemoglobin concentration among children in Ghana: a positive deviance analysis of nationally representative cross-sectional survey data. *Sci Rep* 2020;.
- Aggarwal A, Aggarwal A, Goyal S, et al. Iron-deficiency anemia among adolescents: A global public health concern. *Int J Adv Community Med* 2020;3:35–40.
- Initiative HD. Improving community health in Rwanda. 2023. Available: <https://hdirwanda.org/>
- World Bank. Rwanda's economy continued to achieve strong growth in 2022 despite weakening external demand and restrictive monetary

- policies required to control inflation. 2023. Available: <https://www.worldbank.org/en/country/rwanda/overview>
- 24 FXB International. Integrated approach to reduce malnutrition in Rwanda - FXB | ending poverty, restoring dignity - FXB | ending poverty, restoring dignity. FXB International; 2021. Available: <https://fxb.org/fxb-news/nutrition/rwanda-integrated-approach-to-reduce-malnutrition/>
 - 25 Osazuwa F, Ayo OM, Imade PE. A significant association between intestinal Helminth infection and anaemia burden in children in rural communities of Edo state. *N Am J Med Sci* 2011;3:30–4.
 - 26 Woldie H, Kebede Y, Tariku A. Factors associated with anemia among children aged 6-23 months attending growth monitoring at Tsitsika health center. *J Nutr Metab* 2015;2015:928632.
 - 27 Moschovis PP, Wiens MO, Arlington L, et al. Individual, maternal and household risk factors for anaemia among young children in sub-Saharan Africa: a cross-sectional study. *BMJ Open* 2018;8:e019654.
 - 28 Semahegn A, Tesfaye G, Bogale A. Complementary feeding practice of mothers and associated factors in Hiwot Fana specialized hospital, Eastern Ethiopia. *Pan Afr Med J* 2014;18:143.
 - 29 Duggal MN, Bari A, Iftikhar A. Complementary feeding practices among mothers of children aged six months to two years at children's hospital Lahore. *J Pak Med Assoc* 2020;70:1543–6.
 - 30 Alur P. Sex differences in nutrition, growth, and metabolism in Preterm infants. *Front Pediatr* 2019;7:22:22.
 - 31 Reed BA, Habicht J-P, Niameogo C. The effects of maternal education on child nutritional status depend on socio-environmental conditions. *Int J Epidemiol* 1996;25:585–92.
 - 32 Frost MB, Forste R, Haas DW. Maternal education and child nutritional status in Bolivia: finding the links. *Social Science & Medicine* 2005;60:395–407.
 - 33 Vereecken CA, Keukelier E, Maes L. Influence of mother's educational level on food parenting practices and food habits of young children. *Appetite* 2004;43:93–103.
 - 34 Tesema GA, Worku MG, Tessema ZT, et al. Prevalence and determinants of severity levels of anemia among children aged 6-59 months in sub-Saharan Africa: A Multilevel Ordinal logistic regression analysis. *PLoS One* 2021;16.
 - 35 Seifu BL, Tesema GA. Individual-and community-level factors associated with anemia among children aged 6-23 months in sub-Saharan Africa: evidence from 32 sub-Saharan African countries. *Arch Public Health* 2022;80:183.
 - 36 Ayoya MA, Ngnie-Teta I, Séraphin MN, et al. Prevalence and risk factors of anemia among children 6-59 months old in Haiti. *Anemia* 2013;2013:502968.
 - 37 Leal LP, Filho MB, de PIC, et al. Prevalence of anemia and associated factors in children aged 6-59 months in Pernambuco. *Northeastern Brazil Rev Saude Publica* 2011;Available from:457–66. Available: <https://pubmed.ncbi.nlm.nih.gov/21552753/>
 - 38 Dutta M, Bhise M, Prashad L, et al. Prevalence and risk factors of anemia among children 6–59 months in India: A Multilevel analysis. *Clinical Epidemiology and Global Health* 2020;8:868–78.
 - 39 Zuffo CRK, Osório MM, Taconeli CA, et al. Prevalence and risk factors of anemia in children. *Jornal de Pediatria* 2016;92:353–60.
 - 40 Gondim SSR, Diniz A daS, de SR, et al. Magnitude, time trends and factors associate with anemia in children in the state of Paraíba. *Brazil Rev Saude Publica [Internet]* 2012;Available from:649–56.
 - 41 Malkanthi RLDK, Silva KDRR, Jayasinghe-Mudalige UK. Risk factors associated with high prevalence of anemia among children under 5 years of age in paddy-farming households in Sri Lanka. *Food Nutr Bull* 2010;31:475–82.
 - 42 Rahman MS, Mushfiquee M, Masud MS, et al. Association between malnutrition and anemia in under-five children and women of reproductive age: evidence from Bangladesh demographic and health survey 2011. *PLoS ONE* 2019;14:e0219170.
 - 43 Eadey DEH, Irvonen KAH, Oddinott J, et al. Rural f Ood m Arkets and. 2019;101:1311–27.
 - 44 Kanjilal B, Mazumdar PG, Mukherjee M, et al. Nutritional status of children in India: household socio-economic condition as the Contextual determinant. *Int J Equity Health* 2010;9:19.
 - 45 Houweling TAJ, Ronsmans C, Campbell OMR, et al. Huge poor-rich inequalities in maternity care: an international comparative study of maternity and child care in developing countries. *Bull World Health Organ* 2007;85:745–54.
 - 46 Cogswell ME, Parvanta I, Ickes L, et al. Iron supplementation during pregnancy, anemia, and birth weight: a randomized controlled trial. *The American Journal of Clinical Nutrition* 2003;78:773–81.
 - 47 Baughcum AE, Burklow KA, Deeks CM, et al. Maternal feeding practices and childhood obesity. *Arch Pediatr Adolesc Med* 1998;152.
 - 48 Baker RD, Greer FR, The Committee on Nutrition. Diagnosis and prevention of iron deficiency and iron-deficiency anemia in infants and young children (0–3 years of age). *Pediatrics* 2010;126:1040–50.
 - 49 Deshmukh PR, Garg BS, Sinha N. Epidemiological correlates of nutritional anemia among children (6-35 months) in rural Wardha, central India. *Indian J Med Sci* 2008;62:45.
 - 50 Pasricha S-R, Shet AS, Black JF, et al. Vitamin B-12, folate, iron, and vitamin A concentrations in rural Indian children are associated with continued Breastfeeding, complementary diet, and maternal nutrition. *The American Journal of Clinical Nutrition* 2011;94:1358–70.
 - 51 Howard CT, de Pee S, Sari M, et al. Association of diarrhea with anemia among children under age five living in rural areas of Indonesia. *J Trop Pediatr* 2007;53:238–44.
 - 52 Semrad CE. Approach to the patient with diarrhea and Malabsorption. *Goldman's Cecil Med* 2012;895–913.
 - 53 Ahmed T, Hossain M, Sanin KI. Global burden of maternal and child Undernutrition and Micronutrient deficiencies. *Ann Nutr Metab* 2012;61 Suppl 1:8–17.
 - 54 Watthanakulpanich D, Maipanich W, Pubampen S, et al. Impact of hookworm Deworming on anemia and nutritional status among children in Thailand. *Southeast Asian J* 2011;782–92. Available: <https://pubmed.ncbi.nlm.nih.gov/22299460/>
 - 55 Gium T, Wasie A. The effect of Deworming school children on anemia prevalence: A systematic review and meta-analysis. *TONURSJ* 2018;12:155–61.