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DETERMINANTS OF ANAEMIA IN CHILDREN AGED 6–59 MONTHS IN RWANDA: A MULTILEVEL MIXED-EFFECTS ANALYSIS, 2019-20 RWANDA DEMOGRAPHIC AND HEALTH SURVEY
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E. Gori, G. Mala, F. Kaseke, T. Nyengerai and C. Musarurwa

ABSTRACT

Background: **Anaemia remains a critical public health issue in low- and middle-income countries, particularly affecting children by causing cognitive difficulties, stunted growth, and increased infection risk. Despite its importance, knowledge about the factors influencing anaemia prevalence in young Rwandan children is limited. This study investigated individual and community determinants of anaemia among children aged 6-59 months in Rwanda.**

Methods: **We analysed data from the 2019–2020 Rwanda Demographic and Health Survey (RDHS), focusing on a weighted sample of 3,699 children aged 6-59 months. A stratified two-stage cluster sampling design was used, and data were weighted to adjust for survey design effects. Multilevel mixed-effects logistic regression was performed to assess associations between anaemia and individual/community factors, with adjusted odds ratios (AORs) and 95% confidence intervals (CIs) reported.**

Results: **Children aged 24-42 months (AOR 0.4, 95% CI: 0.34-0.47) and 43-59 months (AOR 0.2, 95% CI: 0.20-0.29) were less likely to be anaemic compared to those aged 6-23 months. The likelihood of anaemia was higher among children who tested positive for malaria (AOR 8.3, 95% CI:**

3.32-20.63), were underweight (AOR 1.3, 95% CI: 1.01-1.78), or those using unimproved toilet facilities (AOR 1.9, 95% CI: 1.22-3.02). Children from lower wealth categories had higher odds of anaemia (AOR 1.3, 95% CI: 1.04-1.52), while those in the Southern (AOR 0.6, 95% CI: 0.45-0.80) and Eastern (AOR 0.7, 95% CI: 0.54-0.94) regions were less likely to be anaemic compared to those in the Northern region.

Conclusion: **Age, underweight, malaria, sanitation, wealth, and regional factors significantly influence anaemia in young children. Further strengthening of the existing interventions such as malaria prevention strategies and treatment, child nutrition programmes, access to improved sanitation and delivery of equitable health and social services can help to further reduce anaemia and improve child health outcomes in Rwanda.**

INTRODUCTION

Anaemia is characterised by insufficient red blood cells or low haemoglobin (Hb) levels, impairing oxygen transport to body tissues. Children are particularly vulnerable due to their rapid growth. The World Health Organization (WHO) defines anaemia in children under five as Hb levels below 11.0 g/dl.[1] Approximately 293.2 million children worldwide suffer from anaemia, with 67.6% in sub-Saharan Africa (SSA), the region with the highest prevalence among low- and middle-income countries (LMICs).[1-3] Anaemia negatively affects immunity, physical and cognitive development, and educational outcomes in children.[4]Anaemia in children has multiple causes, including deficiencies in essential micronutrients (iron, folic acid, vitamin B12, and vitamin A) and infections (e.g., tuberculosis, malaria, and HIV/AIDS). Several factors are associated with anaemia in children, such as maternal age, child's age and sex, malnutrition, household wealth, access to water and sanitation, media exposure, urban or rural residence, maternal health, birth order, family size, and regional differences. [4,5] In Ethiopia, analyses of national health survey data revealed that both individual and community-level factors significantly influence anaemia prevalence among children aged 6–59 months, highlighting the role of nutrition [2] and disease exposure [3,4] in these observed patterns. Similarly, a multilevel analysis from Nepal underscored the impact of social and environmental determinants on anaemia risk in young children[5]. Despite ongoing government and stakeholder efforts across SSA, including Rwanda, anaemia remains a persistent public health concern, hindering progress towards global child health goals.[6,7] While previous studies in Rwanda have linked anaemia to malaria, gastrointestinal infections, and deficiencies in vitamins A and B,[8,9] most are often region-specific or limited to certain subgroups and do not account for the interplay between individual and community-level determinants. There is a critical need for nationally representative analyses that integrate both individual and contextual factors to better characterise the drivers of anaemia in early childhood. This study addresses this gap by assessing the multilevel determinants of anaemia among children aged 6–59 months in Rwanda using data from the

2019–20 RDHS. The primary objective is to identify key individual and community-level risk factors associated with anaemia in this population, thereby informing targeted, context-specific interventions and policies.

METHODS

Study design

This study is based on secondary data from a cross-sectional 2019-20 RDHS, conducted from November 9, 2019, to July 20, 2020(6). The survey employed five questionnaires: household, women's, men's, biomarker, and fieldworker, tailored to capture health and demographic data. The study used the household members' PR Data file. The questionnaires were developed in English, then translated into Kinyarwanda to ensure broad understanding and participation.[10,11]

Study population

The study population comprised 3,699 children aged 6–59 months from the 2019-20 RDHS. Eligibility criteria included children with complete data on anaemia status. Children with missing or incomplete records for anaemia status were excluded from the analysis (Fig 1).

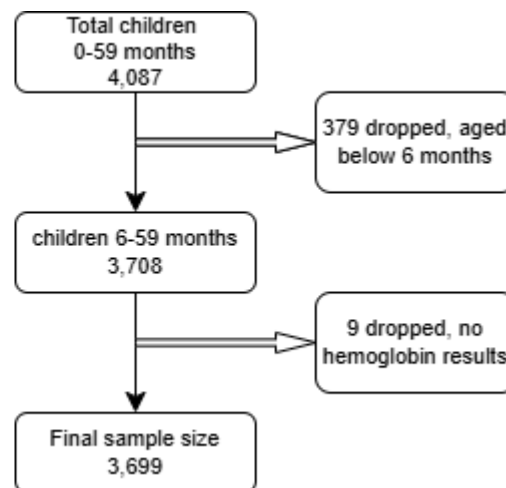

Figure 1: Study population flow diagram

Sampling

The survey used a two-stage design to estimate key indicators across all provinces, districts, and urban and rural areas. In the first stage, 500 clusters (112 urban, 388 rural) were selected. In the second, 13,000 households were systematically sampled from lists compiled in mid-2019.[11] Height and weight were measured for children (0–5 years) and women (15–49 years) during data collection. Re-measurements were conducted the next day for flagged values and for 10% of randomly selected children to ensure data integrity.[10–12]

Anaemia testing

Blood samples were collected using purple-top vacutainers, and Hb concentration was analysed on-site using a portable HemoCue 201+ analyser (HemoCue, Angelholm, Sweden). Mild anaemia was defined as Hb 10.0–10.9 g/dl,

moderate anaemia as Hb 7.0–9.9 g/dl, and severe anaemia as Hb <7.0 g/dl.10–12.[10-12]

Assessment of the nutritional status of children

The nutritional status of children under five was assessed using height-for-age, weight-for-height, and weight-for-age indices, compared against WHO Child Growth Standards. Stunting (chronic undernutrition) was measured by height-for-age; children below two standard deviations (SD) from the median were classified as stunted, and those below three SD as severely stunted. Wasting was evaluated by weight-for-height; children below two SD were categorized as thin, and those below three SD as severely wasted. Underweight, reflecting both acute and chronic undernutrition, was assessed using weight-for-age, with children below two SD considered underweight and those below three SD severely underweight.[10]

Outcome variable

Anaemia status was the outcome variable. This was determined based on Hb levels. According to WHO guidelines, children aged 6-59 months with Hb concentrations below 11.0 g/dL were considered anaemic [6].

Independent variables

Independent variables were analysed across multiple levels. Individual-level factors included the child's age (in months), sex, birth order, and nutritional status (overweight, wasting, stunting, and underweight). Parental characteristics included maternal education and the survival status of both parents. Household-level factors comprised wealth status, household size, drinking water source, ablution facilities, household head's sex, number of children under five, and use of mosquito bed nets. Community-level determinants included region and residence type (urban or rural).

Statistical analysis

Data were analysed using Stata SE Version 18. Descriptive statistics were used to summarise participant demographics and anaemia prevalence across child, household, parental, and community characteristics. Bivariate associations between each explanatory variable and anaemia status were assessed using the Pearson chi-square or Fisher's exact test. Accounting for the RDHS complex survey design, we performed multilevel mixed-effects logistic regression to estimate random effects at different clustering levels using sample weights. Four models were compared: null model, Model I (dependent factors), Model II (individual-level factors), and Model III (parental and community-level factors). Clustering was assessed via the Intra-class Correlation Coefficient (ICC). Model selection relied on the Median Odds Ratio (MOR), Akaike Information Criterion (AIC), and deviance, with the model minimizing these criteria selected for interpretation. Variable selection for multivariable modelling followed a combined approach. Variables were retained based on theoretical relevance informed by previous literature, as well as empirical evidence from the bivariate analysis. Specifically, variables with a $p < 0.25$ in bivariate analysis were included in multivariable analysis to avoid excluding potentially important predictors. This threshold was chosen to be inclusive in identifying candidate variables for further adjustment. Final model estimates were reported as adjusted odds ratios (AORs)

with corresponding 95% confidence intervals (CIs).

Ethical considerations

Approval for data access was obtained from the Demographic Health and Survey (DHS) Program (https://goo.gl/ny8T6X). Data were accessed on February 19, 2024, from the DHS program (https://dhsprogram.com/Data/). The survey protocol, including procedures for obtaining informed consent was reviewed and approved by the Rwanda National Ethics Committee (RNEC) and ICF Review Board (#180657.0.001). Participant data in the DHS was anonymized, and no identifiable information was available to the authors.

RESULTS

In this study, 35.6% of the participants were aged 24-42 months and constituted the highest proportion, followed by those aged 6-23 months (33%), and 50.3% of the participants were males. Regarding parent-related characteristics, most mothers attained only primary-level education (64.7%), and 99.3% were alive. Similarly, 97.3 proportion of the fathers were alive. Based on the household wealth status, 44.6% of the participants were classified as poor, 18.8% as middle-income, and 36.7% as rich. Furthermore, 74.5% of the households were headed by males and 79% of the children resided principally in rural areas. The Western (24.7%) and northern (24.7%) regions had the highest proportion of children, whereas Kigali had the lowest (11.2%) (Table 1a and b)

Table 1a

Descriptive child and parental-related characteristics of children aged 6-59 months, Rwanda

Variables	Categories	Frequency (N=3,699)	Unweighted (%)	Weighted (%)
Child characteristics				
Child age (in months)	6–23	1,222	33.04	33.48
	24–42	1,318	35.63	35.21
	43–59	1,159	31.33	31.32
Sex of child	Male	1,862	50.34	50.24
	Female	1,837	49.66	49.76
Birth order	<5	2,686	72.61	72.87
	≥5	1,013	27.39	27.13
Overweight	Yes	188	5.08	5.12
	No	3,511	94.92	94.88
Wasting	Yes	40	1.08	1.07
	No	3,659	98.92	98.93
Stunting	Yes	1,302	35.20	34.83
	No	2,397	64.80	65.17
Underweight	Yes	295	7.98	7.88
	No	3,404	92.02	92.12

Malaria	Positive	34	0.92	0.85
	Negative	3,664	99.08	99.15
Parental-related characteristics				
Mothers educational level	No formal education	412	11.91	11.97
	Primary education	2,237	64.65	64.27
	Secondary education	649	18.76	19.69
	Higher education	162	4.68	4.08
Mother alive	Yes	3,672	99.27	99.25
	No	23	0.62	0.61
	don't know	4	0.11	0.14
Father alive	Yes	3,600	97.32	97.45
	No	64	1.73	1.60
	don't know	35	0.95	0.94

Table 1b

Descriptive household and community-level characteristics of children aged 6-59 months, Rwanda

Variables	**Categories**	**Frequency (N=3,699)**	**Unweighted (%)**	**Weighted (%)**
Household characteristics				
Household wealth status	Poor	1,648	44.55	43.44
	Middle	694	18.76	19.48
	Rich	1,357	36.69	37.08
Number of household members	<5	1,327	35.87	36.13
	5-8	2,135	57.72	57.42
	≥9	237	6.41	6.45
Source of drinking water supply	Improved	2,936	79.37	79.45
	Unimproved	763	20.63	20.55
Toilet facilities	Improved	3,599	97.30	97.36
	Unimproved	100	2.70	2.64
Sex of household head	Male	2,755	74.48	75.97
	Female	944	25.52	25.03
Children under-5 years	<2	1,786	48.28	47.65
	≥2	1,913	51.72	52.35
Use of mosquito bed net	Yes	2,677	72.37	72.32
	No	1,022	27.63	27.68
Community-level characteristics				
Residence	Urban	779	21.06	17.04
	Rural	2,920	78.94	83.96
Region	Kigali	414	11.19	13.56
	South	863	23.33	20.35
	West	912	24.66	23.50
	North	595	16.09	15.48

	East	915	24.74	27.10

Child anaemia prevalence by region

The overall prevalence of anaemia across all regions was 36%. Two regions, Western (41%) and Northern (41%), had anaemia prevalence above the national average, while Kigali (37%), Southern (32%), and Eastern (33%) were below the overall estimate (Fig 2). The districts with the highest prevalence of anaemia were Nyamagabe (48%) in the southern region and Ngororero (52%) in the western region. Heterogeneity analysis indicated significant variation across regions, with the highest heterogeneity observed in western region ($I^2 = 74.9\%$) and overall ($I^2 = 68.9\%$) regions.

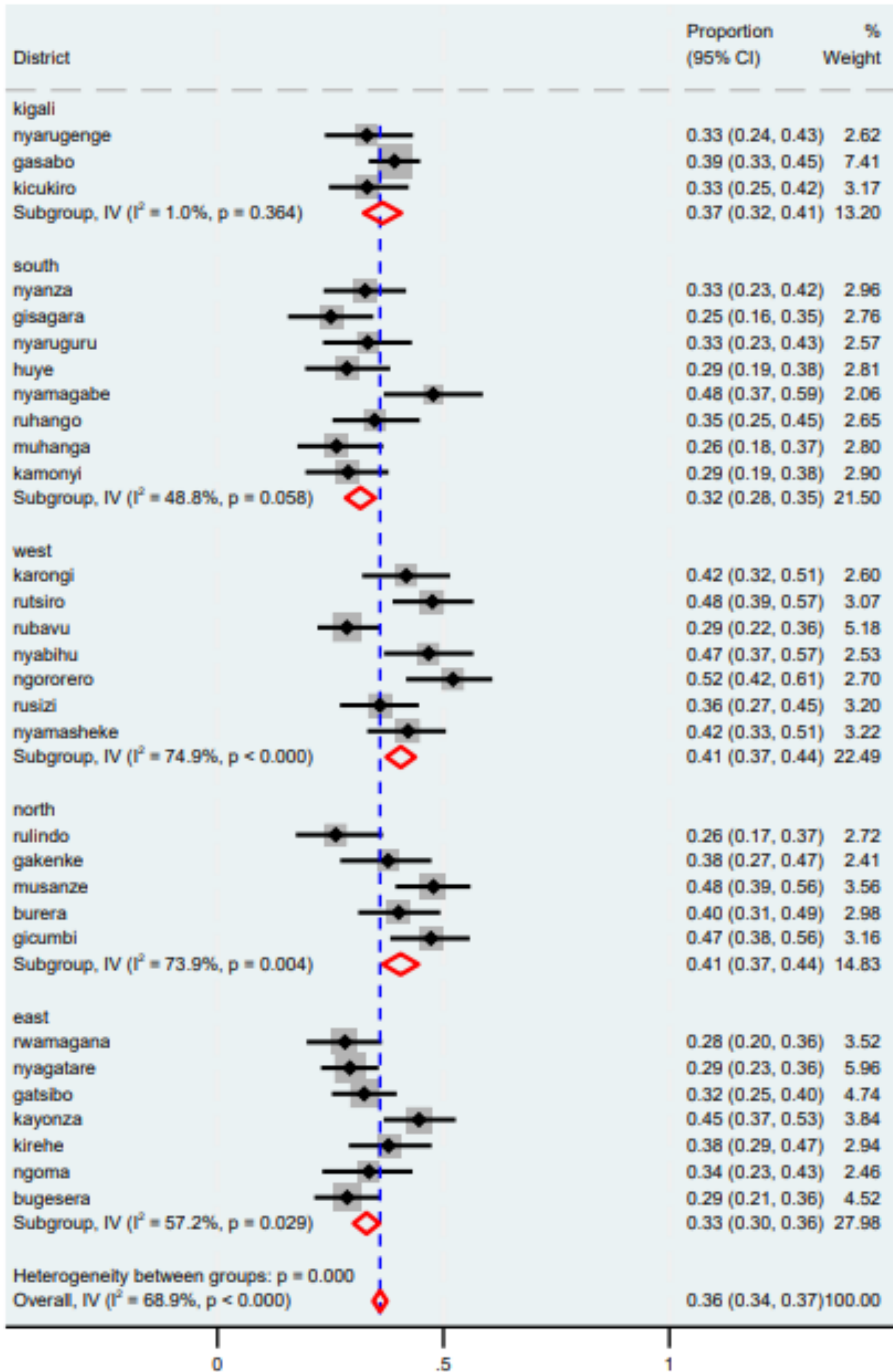

Fig 2: Forest plot of the prevalence of anaemia across different districts by regions of Rwanda

Anaemia prevalence and severity

Children aged 6–23 months had the highest anaemia prevalence (52.9%), with 28% classified as mild and 24.5% as moderate (Table 2). Anaemia prevalence declined with age, affecting 32.9% of children aged 24–42 months and 23.3% in those aged 43–59 months. Higher anaemia prevalence was also observed among malaria-positive children (78.2%) compared to malaria-negative children (36.2%), and among those in households with unimproved toilet facilities (52%) versus improved facilities (36.2%). Children from poor households had a prevalence of 39.5% compared to middle-income (37.1%) and rich households (33.0%). Regional variation was also observed, with the highest prevalence in the northern (41.2%) and western (41.1%) regions and the lowest in the southern region (32.2%).

Table 2

Prevalence and severity of anaemia based on the child-related, household, paternal, and community-level characteristics in Rwanda (N=3,699) – [Survey weighted]

Variable	Categories	Anaemia status and severity level (%)				Overall anaemia prevalence (%)
		Severe	Moderate	Mild	Not anaemic	
Child age (in months)	6-23	0.54	24.45	27.95	47.06	52.94
	24-42	0.21	11.91	20.76	67.12	32.88
	43-59	0.09	8.15	15.09	76.68	23.33
Child sex	Male	0.36	15.74	21.91	61.99	38.01
	Female	0.21	14.11	20.86	64.82	35.18
Overweight	Yes	0.00	18.00	19.64	62.36	37.64
	No	0.30	14.76	21.48	63.46	36.54
Under-weight	Yes	0.71	20.76	21.10	57.43	42.57
	No	0.25	14.43	21.41	63.91	36.09
Stunting	Yes	0.32	16.62	21.92	61.13	38.86
	No	0.26	14.02	21.10	64.61	35.38
Malaria Status	Negative	0.28	14.55	21.40	63.77	36.23
	Positive	0.00	57.29	20.86	21.85	78.15
Wasting	Yes	0.00	25.55	13.88	60.57	39.43
	No	0.29	14.81	21.47	63.43	36.57
Women education	No education	0.30	17.29	22.89	59.51	40.48
	Primary	0.32	15.11	21.12	63.45	36.55
	Secondary	0.31	13.70	22.10	63.89	36.11
	Higher	0.00	8.83	22.41	68.76	31.24
Water source	Improved	0.25	15.10	21.34	63.31	36.69
	Unimproved	0.41	14.42	21.27	63.91	36.10
Sex of household head	Male	0.31	15.04	21.79	62.86	37.14
	Female	0.20	14.59	20.19	65.02	34.98

Toilet facilities	Improved	0.29	14.78	21.11	63.82	36.18
	Unimproved	0.00	20.34	31.64	48.02	51.98
Wealth index	Poor	0.13	17.29	22.04	60.55	39.46
	Middle	0.45	16.10	20.58	62.87	37.13
	Rich	0.38	11.55	21.05	67.02	32.98
Residence	Urban	0.33	12.36	21.48	65.83	34.17
	Rural	0.27	15.46	21.37	62.90	37.10
Region	Kigali	0.31	13.01	23.28	63.40	36.60
	South	0.33	13.52	18.33	67.81	32.18
	West	0.11	20.35	20.62	58.91	41.08
	North	0.37	16.54	24.33	58.76	41.24
	East	0.33	11.33	21.71	66.63	33.37
Overall prevalence (95% CI)		0.3(0.15, 0.51)	15(13.8, 16.1)	21(20.1, 22.7)	63(61.9, 64.9)	36(35.1, 38.1)

Model selection

Among the multilevel mixed-effects logistic regression models assessed, Model III had the best model fit, with a cluster variance (0.260 [95% CI: 0.166, 0.409]), Median Odds Ratio, and intra-class correlation coefficient (ICC) of 0.074, indicating inter-cluster heterogeneity and an observable clustering effect. In addition, Model III showed the lowest log-likelihood ratio (LLR) (-2300.11) and deviance (4600.23), which demonstrates its superior fit to the observed data. Furthermore, with an Akaike Information Criterion (AIC) of 4630.23, Model III effectively balanced the goodness of fit and model complexity (Table 3).

Table 3

Model selection summary

Parameter	Null Model	Model 1	Model II	Model III
Community Level Variance	0.295 [0.198, 0.441]	0.297 [0.196, 0.452]	0.269 [0.177, 0.410]	0.260 [0.166, 0.409]
ICC	0.0825	0.0829	0.0757	0.0735
LLR	-2460.16	-2310.79	-2451.74	-2300.11
Deviance	4920.31	4621.59	4903.48	4600.23
MOR	1.326	1.328	1.293	1.283
AIC	4924.31	4643.59	4915.48	4630.23

Key: AIC, Akaike Information Criterion; ICC, intra-class correlation coefficient; LLR, log-likelihood ratio; MOR, Median Odds Ratio.

Factors associated with child anaemia

Results from multilevel mixed-effects logistic regression showed that children aged 24–42 months had a significantly lower odds of anaemia (AOR 0.4, 95% CI: 0.34–0.47) compared to those aged 6–23 months (Table 4). Similarly, children aged 43–59 months were less likely to be anaemic (AOR 0.2, 95% CI: 0.20–0.29). Malaria positivity was strongly associated with increased odds of anaemia (AOR 8.3, 95% CI: 3.32–20.63). Other factors

associated with higher odds of anaemia included being underweight (AOR 1.3, 95% CI: 1.01–1.78), living in households with unimproved toilet facilities (AOR 1.9, 95% CI: 1.22–3.02), and belonging to poor households (AOR 1.3, 95% CI: 1.04–1.52). Compared to children in the Northern region, those in Southern (AOR 0.6, 95% CI: 0.45–0.80) and Eastern (AOR 0.7, 95% CI: 0.54–0.94) regions were less likely to be anaemic. Random-effects analysis indicated community-level variations in anaemia prevalence (Table 3).

Table 4

Multilevel mixed-effects logistic regression for individual and community level factors associated with anaemia in children aged 6–59 months, [Rwanda - RDHS PR Data, 2019/20, N = 3,699]

Variable	Categories	COR (95% CI)	AOR (95% CI)
Child age (in months)	6-23	Reference	
	24-42	0.4(0.33, 0.50) ***	0.4(0.34, 0.47) ***
	43-59	0.2(0.20, 0.30) ***	0.2(0.20, 0.29) ***
Child Sex	Male	Reference	
	Female	0.9(0.76, 1.02)	0.9(0.77, 1.03)
Under-weight	No	Reference	
	Yes	1.3(1.02, 1.75) *	1.3(1.01, 1.78) *
Stunting	No	Reference	
	Yes	1.1(0.95, 1.30) *	1.0(0.85, 1.19)
Malaria Status	Negative	Reference	
	Positive	5.9(2.27, 15.56) ***	8.3(3.32, 20.63) ***
Toilet facilities	Improved	Reference	
	Unimproved	1.9(1.27, 2.86) **	1.9(1.22, 3.02) **
Wealth index	Rich	Reference	
	Middle	1.2(0.98, 1.54)	1.2(0.97, 1.49)
	Poor	1.3(1.07, 1.53) ***	1.3(1.04, 1.52) *
Region	North	Reference	
	Kigali	0.8(0.59, 1.12)	0.9(0.63, 1.24)
	West	1.0(0.77, 1.37)	1.0(0.77, 1.34)
	South	0.7(0.50, 0.89) **	0.6(0.45, 0.80) ***
	East	0.7(0.55, 0.94) *	0.7(0.54, 0.94) *

Key: COR, Crude odds ratio; AOR, Adjusted odds ratio; CI, Confidence interval.
**p-value < 0.05; **p-value < 0.01; ***p-value < 0.001*

DISCUSSION

This study examined the determinants of anaemia in children aged 6–59 months in Rwanda, where the overall prevalence was 36%. This is lower than Liberia[16] and Togo [17] (>70%) where similar studies were conducted. Regional variations were observed, with the Northern and Western regions of Rwanda showing over 40% prevalence, reflecting probable discrepancies in healthcare, economic development, and environmental factors. A study on iron-rich food consumption

found lower overall consumption which might explain the higher prevalences of anaemia in some regions[18]. Nutritional interventions may be needed to address regional disparities in anaemia prevalence.

The prevalence of anaemia among children in Rwanda aligns with the findings of African and Chinese studies. In Ghana, children under two had higher risk of anaemia, [19] and in China, the highest rates were seen in children aged 6-12 months, [20] similar to the trends observed in Sudan [21] and Uganda. [22] In this study, children aged 24-59 months had a lower risk of anaemia compared to those aged 6-23 months, suggesting that age may offer some protection due to improved resilience or dietary habits.[23-25] In addition, children aged 6-23 months primarily acquire iron from breast milk. The elevated occurrence of anaemia could be linked to maternal iron deficiency [26] resulting from intestinal parasite infections and poor nutrition.[9, 19, 27] Maternal anaemia contributes to the cycle of childhood anaemia, emphasizing the need for improved maternal health.

In agreement with previous studies, malaria-infected children demonstrated a significantly higher risk of anaemia. In Uganda, over 60% of children under five are anaemic, with malaria and lack of mosquito nets cited as key risk factors.[22] Malaria is a well-known risk factor for anaemia, given its ability to destroy red blood cells and impair their production, resulting in haemolytic anaemia. [28] This emphasizes the critical importance of malaria prevention and treatment programs in reducing the prevalence of anaemia among children.

Nutritional deficiencies, including iron and vitamin deficiencies, contribute to increased susceptibility to anaemia and are directly linked to elevated anaemia rates in children, as observed in South Africa and other similar settings. [11, 19 22, 29] This demonstrates the significance of malnutrition in anaemia, particularly deficiencies in essential nutrients such as iron. In this study, underweight children were found to have a higher risk of anaemia. Therefore, interventions aimed at addressing nutritional deficiencies are essential to mitigate the burden of anaemia and improve child health outcomes.

This study further revealed that poor sanitation is a determinant of anaemia in children. Children from households with unimproved toilet facilities exhibited a higher risk of anaemia. Poor sanitation and hygiene practices can lead to gastrointestinal infections and parasitic infestations, which contribute to chronic inflammation and poor nutrient malabsorption, thereby predisposing children to anemia.[9,29] Consistent with this finding, children from economically disadvantaged households had a higher risk of anaemia than those from wealthier households. Socioeconomic status influences access to healthcare, nutritious food, and overall living conditions, all of which affect the risk of anemia.[2,4, 30] Thus, efforts to address poverty and improve access to healthcare and nutritious food may help mitigate the risk of anaemia in children.

Study limitations and strengths

This study was constrained by its cross-sectional design, which prevents the determination of causal links between the identified factors and anaemia. Additionally, reliance on self-reported data may introduce a recall bias, potentially affecting the accuracy of the

results. Furthermore, the analysis did not account for certain unmeasured confounding variables such as dietary intake and parasitic infections which are known to influence anaemia risk and may have influenced the observed associations. Despite these limitations, this study benefits from the use of nationally representative data from the RDHS, which enhances the generalizability of the findings. A large sample size and rigorous sampling methodology increased the reliability and validity of the results.

CONCLUSION

This study identified age, malaria infection, underweight, sanitation facilities, socioeconomic status, and geographical region as key factors associated with anaemia among children aged 6-59 months. While the study did not directly evaluate interventions, potential strategies to reduce the burden of anaemia may include further strengthening of malaria control efforts, maternal healthcare and child nutrition, access to clean water and sanitation, deworming programs, and efforts to address underlying socioeconomic disparity causes of anaemia in Rwanda.

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Disclosure
Authors declare no conflicts of interest.

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