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Exploring the prevalence and association between nutritional status and asymptomatic malaria in Rwanda among under-5 children: a cross-sectional analysis

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Abstract

Background Undernutrition and severe malaria continue to be major public health concerns worldwide, particularly in African countries. While the association between malaria and malnutrition has been widely studied in various settings, limited research has focused on asymptomatic malaria and its link to nutritional status in Rwanda, leaving a gap in understanding this relationship in the local context. This study aimed to investigate the possible relationship between children's nutritional health and asymptomatic malaria infections. Specifically, the study assessed the prevalence of undernutrition and asymptomatic malaria infection in relation to implemented policies and the link between stunting, wasting, underweight, and asymptomatic malaria infections.

Methods Data from three Demographic and Health Surveys (DHS) conducted in Rwanda in 2010, 2014–15, and 2019–20 were used in the study, including children aged 6 to 59 months and confirmed malaria diagnoses via blood smear. The odds ratio of stunting, underweight, and wasting on malaria outcomes were calculated using logistic regression, with and without adjusting for factors such as age, gender, mother's education, wealth index, type of residence, and region within each survey. The present study examined data from three DHSs conducted in Rwanda, which included 10,411 children aged less than five years who were tested for malaria and 11,424 children who had anthropometric measurements. Despite this variation, the available sample size ($n = 10,409$) remains robust for drawing meaningful conclusions, and potential biases due to missing data in the analysis were taken into account. This study used unadjusted (OR) and adjusted odds ratios (AOR) to evaluate the relationships between stunting, underweight, age, wealth index, and malaria outcomes. All independent variables with a p-value below 0.05 in the unadjusted regression were included and considered significant in the adjusted regression analysis. A $p\text{-value} < 0.05$ was used to determine statistical significance.

Results Asymptomatic malaria was found to be present in 1.3% (95% confidence interval (CI) 1.14%–1.59%) of the population (140/10,411). The study also discovered that 38.3% (95% CI 37.42%–39.21%) of the children were

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stunted (Z-score < − 2.0). Moreover, the results indicate that malaria was more frequent in children with stunting (OR = 1.85, 95% CI = [1.32; 2.59], p < 0.001). Underweight children were also found to have an increased prevalence of malaria (AOR = 1.59, 95% CI [1.14–2.95], p = 0.01). Age was also an important variable correlated with malaria infection since the prevalence of malaria was found to be higher in children over 24 months of age (AOR = 2.72, 95% CI [1.78–4.16], p < 0.001). Children from the richest families were found to be protected from malaria AOR = 0.38 (95% CI [0.24–0.58], p < 0.001) in all 3 DHS.

Conclusion This study revealed that undernutrition indexes such as stunting and underweight as well as poor wealth index are significant risk factors for asymptomatic malaria in children under the age of five years. Malaria itself can worsen nutrition status, creating a vicious cycle. Monitoring and enhancing this dual relationship of nutritional status and malaria highlights the essential needs of children in this age group in malaria-endemic settings.

Keywords Asymptomatic malaria, Nutritional status, Malnutrition in children under 5, Rwanda, RDHS, Cross-sectional study

Background

Malaria and malnutrition are major contributors to morbidity and mortality, particularly among infants and children under five in sub-Saharan Africa (SSA) [1, 2]. Therefore, malaria and stunting are of high global health concerns. These health issues are directly related to achieving several Global Sustainable Development Goals (SDGs); mainly no poverty, zero hunger, good health and well-being, and possibly sustainable communities, reducing inequalities and increasing descent work and economic growth. According to the Global Technical Strategy for Malaria, to improve health, the malaria burden must be reduced by 75% from the baseline level in 2015 by 2030 [3, 4]. Additionally, the WHO and UNICEF alongside their stakeholders, aim to reduce the number of stunted children by 40% and wasting to < 5% by 2025 [5].

Malaria parasitaemia persists in immune populations, resulting in asymptomatic malaria cases, which contributes to perennial malaria transmission [6] and can also mediate malnutrition and anaemia [2, 7]. Stunting, or low height for age determined by the Z scores, is defined as a sign of chronic undernutrition, reflecting insufficient intake of both the quantity and the quality of the recommended diet. Furthermore, while global consumption of red meat and sugary foods has increased, the Comprehensive Food Security and Vulnerability and Nutrition Analysis Survey (CFSVA2022) report revealed that only 2% of children under five in Rwanda consumed meat and organ meat [8].

This inadequate nutrition compromises daily energy intake, micronutrients, and vitamin intakes, resulting in delayed growth and development, as well as reduced immune system functionality in children under the age of five, which exacerbates infectious diseases such as malaria [2, 9].

According to the 2024 World Malaria Report of the World Health Organization (WHO), there were an estimated 263 million cases and 597,000 deaths from malaria in 85 endemic countries and territories worldwide. Unfortunately, over 95% of the malaria burden, including morbidity and mortality, is reported in SSA [10]. Meanwhile, 149.2 million under five children are too short for their age (stunted) and 45.4 million children have low weight for height (wasted) worldwide [11–13]. Similarly, the highest burden of malnutrition is recorded in SSA [14, 15]. The coexistence and double burden of malaria and undernutrition are major health issues of concerns, and the co-burden among same individuals is very common, particularly in SSA region [12–15]. Children affected by both conditions have been shown to suffer from long-term complications such as deficits in physical and cognitive development and poor school performance [16, 17].

Rwanda has recorded a decline in disease burden over the last two decades, as indicated by the substantial progress in controlling malaria and improving nutrition status. This progress has led to a reduction in stunting from 38% in 2015 to 33.1% in 2020 [18]. Similar progress was achieved in malaria control, with prevalence decreasing from 40.5% in 2016 to 5% in 2022. This success is largely attributable to the country's improved healthcare infrastructure, increased deployment of proven malaria interventions like indoor residual spraying of households with insecticide (IRS) and universal coverage with insecticide-treated nets (LLINs), expanded community and stakeholder engagement, and improved at-home case management of childhood illness (pneumonia, diarrhoea, and malaria) [19, 20]. Despite these gains, asymptomatic malaria remains a critical public health concern. Unlike symptomatic malaria, which prompts treatment and intervention, asymptomatic infections often go undetected, serving as silent reservoirs that sustain transmission. Given that children with chronic malnutrition may have prolonged parasite carriage, the study focused on asymptomatic malaria to better understand the interplay between nutritional deficiencies and subclinical malaria infections. The investigation of asymptomatic malaria yields valuable insights into hidden reservoirs of infection and contributes to the development of targeted strategies for malaria elimination.

Moreover, evidence shows that the current malaria and nutritional improvements are highly vulnerable, particularly when the health system is confronted with a health emergency like the COVID-19 pandemic crisis. The COVID-19 pandemic has reversed a significant proportion of the progress in reducing malaria and nutrition-related morbidity and mortality [21–23]. Therefore, there is an urgent need to identify novel strategies to support the existing ones.

Despite the high achievements in reducing malaria and undernutrition in Rwanda, little is known about the relationship between nutritional status and malaria, and the currently available data/information are not conclusive [24]. A prospective study conducted by Kateera et al. [25, 25] concluded that undernutrition is prevalent in non-malaria endemic district in Rwanda. Unfortunately, the study design did not allow to conclude on a relationship as no nutritional parameters were studied.

Therefore, the primary objective in this study was to explore the association between undernutrition parameters and the prevalence of asymptomatic malaria in children under five in Rwanda. It is worth noting that while malaria and malnutrition often co-exist, this study does not establish a causal relationship between these conditions. Instead, this research examines an association, recognizing that multiple factors—including socio-economic determinants, immune function, and nutritional deficiencies—may contribute to the observed patterns. Further research is needed to explore the bio-physiological and immunological pathways linking these conditions.

While the primary focus of this study is the association between undernutrition and asymptomatic malaria, the authors, also conducted a broader risk factor analysis to identify key determinants influencing asymptomatic malaria prevalence. This approach ensures a more comprehensive understanding of malaria risk beyond nutritional factors, accounting for socio-economic and environmental influences. Consequently, this work focused on the analysis of policies, incidents, and nutrition status with respect to malaria outcomes.

Methods

Data source

All malaria and nutrition data were extracted from three consecutive Demographical Health Surveys (DHSs), that were conducted in Rwanda in 2010–2011, 2014–15, and 2019–20; data is publicly available at http://www.measuredhs.com/. Approval to download and use the data was obtained by ICF Macro.

Setting and population

Data on asymptomatic malaria and nutrition status were extracted from the Rwanda DHS in 2010, 2015, and 2020. Children who were tested for biomarkers and malaria infection and those with an anthropometric and demographic record were selected.

Study design

To enable national representation of important indicators, including rural and urban zones in all five regions, the survey design followed a two-stage selection level. Home-level enumeration, which entailed methodically identifying households in various regions, was the initial step. Proportional representation was ensured in the second step of respondent selection. This indicates that the probability of selecting a household was modified according to its size, where "size" was defined as the total number of people living in each household. The selection was done with a probability proportional to the size of each household. This approach ensures that larger households, which may be more common in certain regions or zones, have a higher chance of being included in the survey, contributing to a sample allowing for unweighted analyses. Specifically, women aged between 15 and 49 who were present in the household on the night of the poll were chosen as respondents. Additionally, all surveys concerning children included optional components and/or biomarkers for a more comprehensive understanding of relevant indicators [18].

For this research, data on malaria and nutrition were combined from three datasets collected between September 2010 and March 2011 (DHS 2010), November 2014 and April 2015 (DHS 2015), and November 2019 and July 2020 (DHS 2020).

Situation and policy analysis

Initially, reviews of national strategic documents, including policies, strategies, guidelines, and annual reports were conducted to consolidate knowledge on essential malaria and nutrition-related issues and their control in Rwanda from 2000 to 2022. This evaluation included published and unpublished reports, such as health-related documents, ministerial instructions, yearly reports, and programme review reports. Given that secondary analyses, such as the DHS, do not account for policy impact, the goal was to explore the influence of key interventions in reducing malaria and nutritional indicators.

Malaria and nutrition variables

This study determined variables of interest, including the definitions, indicators, and other factors related to asymptomatic malaria infection and child nutrition status, according to the WHO guidelines. Then, the relevant data from the DHS surveys were extracted. These selected variables are described in Table 1 [18, 26–28].

Definition of malaria variables

Asymptomatic malaria infection was confirmed by a blood smear. Children who were positively diagnosed with malaria without showing clinical symptoms were classified as asymptomatic cases.

Malaria prevalence: proportion of malaria cases confirmed by blood smear in a specific population at each time [26].

Nutrition status variables

The undernutrition is defined as a lack of energy-protein intake and nutrients to meet a human/person needs to preserve worthy health [29]. Its indicators were identified by anthropometric variables, mainly height and weight, in combination with age and sex. The age was measured by the difference between the date of the day of the month of the survey and the date of birth [30], the height and weight were measured in centimetres and grams, respectively, using calibrated instruments. Since measurements of children in the field are prone to a small margin of errors that can mislead outcome interpretations, 10% of the measured children were randomly selected for a second measurement. To ensure the accuracy and quality of the collected data, the data collectors were blinded to the previous measurements. Then, using the WHO sex and age distribution as a reference population for standardization, the three primary indices of child development were determined, including ratios of the child's height to age (stunting), body weight to height (wasting), and weight to age (underweight) [16, 31].

Stunting, wasting, and underweight were examined as distinct independent variables, each with standalone classifications. Stunting was characterized by children having a height or length-for-age Z-score (HAZ) falling below − 2.0, while severe stunting was identified when the HAZ was below − 3.0 and normal range values between − 2.0 and + 2.0. This was classified into binary levels; children with severe or moderate stunting were jointly classified as stunted. Wasting was determined by a weight-for-height or length Z-score (WHZ) below − 2.0; likewise, severe wasting was defined by a WHZ below − 3.0 and normal range values between − 2.0 and + 2.0. This was classified into binary levels; a child with severe and moderate wasting was classified as wasted. Underweight was determined in children with a weight-for-age Z-score (WAZ) below − 2.0, while severe underweight was indicated when the WAZ fell below − 3.0 and normal range values between − 2.0 and + 2.0. This was classified

Table 1 Factors affecting child nutritional status: definitions and types of determinants

Determinants	Variable definition and type
Asymptomatic malaria	Positive Blood smear with no symptoms
Stunting	Z-score < − 2.0
Moderate stunting	Height/length for age ≥ − 3.0 and < − 2.0
Severe stunting	Height/length for age < − 3.0
Wasting	Z-score < − 2.0
Moderate wasting	Weight for height/length ≥ − 3.0 and < − 2.0
Severe wasting	Weight-for-length/height < − 3.0
Underweight	Z-score < − 2.0
Moderate underweight	Weight-for-age ≥ − 3.0 and < − 2.0
Severe underweight	Weight-for-age < − 3.0
Age	< 24 months or ≥ 24 months (binary)
Sex	Female/male (binary cisgender)
Residence	Rural or urban (binary)
Maternal education	No education of the child's mother or at least primary school of the child's mother or secondary and high school of the child's mother
Wealth index	Poor: poorest and poorer categories Rich: middle, richer, and richest categories
Region	Kigali, South, North, Western, or East
Year of the survey	2010, 2015, 2020
Iodine	Iodine levels in salt are determined at RBS per salt specimens collected at households

into binary levels in the same way; children with severe or moderate underweight were classified as underweight [18]. The WHO Global Database on Child Growth standards use the z-score concept applied to the normal curve and assumes the cutoff points of − 2.0 or + 2.0 to define deficit or excess for a given anthropometric index. The percentage of individuals beyond these cutoff points in the anthropometric pattern is about 2.3%, respectively. A prevalence of 2.3% below or above two for any anthropometric index is considered as "acceptable" since this is the proportion found in the reference population [32].

Anaemia is defined as presenting a haemoglobin ranging below the standard range 11.0 g/dl, and it is classified into three categories. It is classified as severe anaemia when the haemoglobin is below 7.0 g/dl, moderate when haemoglobin ranges between 7.0 g/dl and 9.9 g/dl, and mild anaemia when it is between 10.0 to 10.9 g/dl [33].

Social demographic factors of the child and the mother

The sociodemographic factors include age, gender, residency, region, mother's education, and wealth index. The *age of the child* was classified into three categories based on < 24 months or ≥ 24 months. The *gender* of the child was also categorized as binary according to its cisgender. The *child residency* was classified into urban and rural.

Region: Rwanda is subdivided into five areas according to four provinces (East, North, South, Western) and the City of Kigali. [34, 35]

Mother education: A child's mother's educational background includes no education, primary, secondary, and high school; it was categorized into three levels. Non-educated mothers are designated as having no scholarship, and those with primary education are categorized separately whereas secondary or high school education are categorized together [36].

Wealth index: The distribution of the wealth index, encompassing economic strata from the poorest to the richest (poorest, poorer, middle, richer, and richest), was organized into quintiles, providing a graded representation of household socio-economic status. This categorization was grouped into two levels: the first level included the poorest and poorer categories, classified as poor, while the second level included the middle, richer, and richest categories, classified as rich. This classification follows standard DHS methodology for wealth index calculation [18].

Statistical analyses

Multivariable logistic regression analysis and decomposition techniques were used to assess which predictors were statistically significant in the association between asymptomatic malaria prevalence and nutritional status. This study's dependent variable was dichotomous: malaria was either positive or negative in children aged 6 to 59 months and children also could have or not have clinical malaria symptoms.

To determine the malaria risk factors, a full logistic regression model with all variables and calculated the odds ratio along with a 95% confidence interval and p-value were computed. All independent variables with a p-value below 0.05 in the unadjusted regression were included and considered significant in the adjusted regression analysis. The model was adjusted for age, gender, and the wealth index, and tested for multicollinearity among variables. A diagnostic was performed, and tolerance was deemed acceptable with $GVIF^{(1/(2df))} < 2$ for categorical variables and $VIF < 10$ for continuous variables. Then backward stepwise selection was used for retaining only variables that remained significant at an alpha level of 0.05 in the final model [37].

Furthermore, the three distinct datasets were combined to create a dataset for the final regression model for assessing the relationship between malaria and nutrition factors. To account for potential temporal variations in socio-demographic and economic conditions, survey year was included as an adjustment variable in all regression models. Stata/SE version 15.1 was used for statistical analysis.

Ethics

This study used secondary data collected through the national DHS without personal identifiers. The DHS surveys received ethical approval from the Rwanda National Ethics Committee [18] and the ICF Institutional Review Board and all data are publicly available on the website: www.statistics.gov.rw. Therefore, no additional ethical approval was required for this secondary analysis.

Results

Situation and policy analysis

Figure 1 provides two key pieces of information: (1) policies and guidelines to support nutrition interventions in Rwanda, and (2) trends in stunting prevalence among children under five years from 1992 to 2020. The data shows that Rwanda has made progress in reducing stunting over the past few decades, from 56.8% in 1992 to 33.1% in 2020 reflecting a decline of 23.7%. Various health, nutrition, and development policies and interventions introduced during this period likely contributed to this decline. This figure demonstrates the positive impact of policy initiatives on nutritional outcomes in Rwanda.

Figure 2 shows malaria interventions (LLINs and IRS) in Rwanda (2008–2022), highlighting implementation districts, data from DHS, and epidemiological impacts. Various interventions, such as Long-Lasting Insecticidal Nets (LLINs) and Indoor Residual Spraying (IRS), were

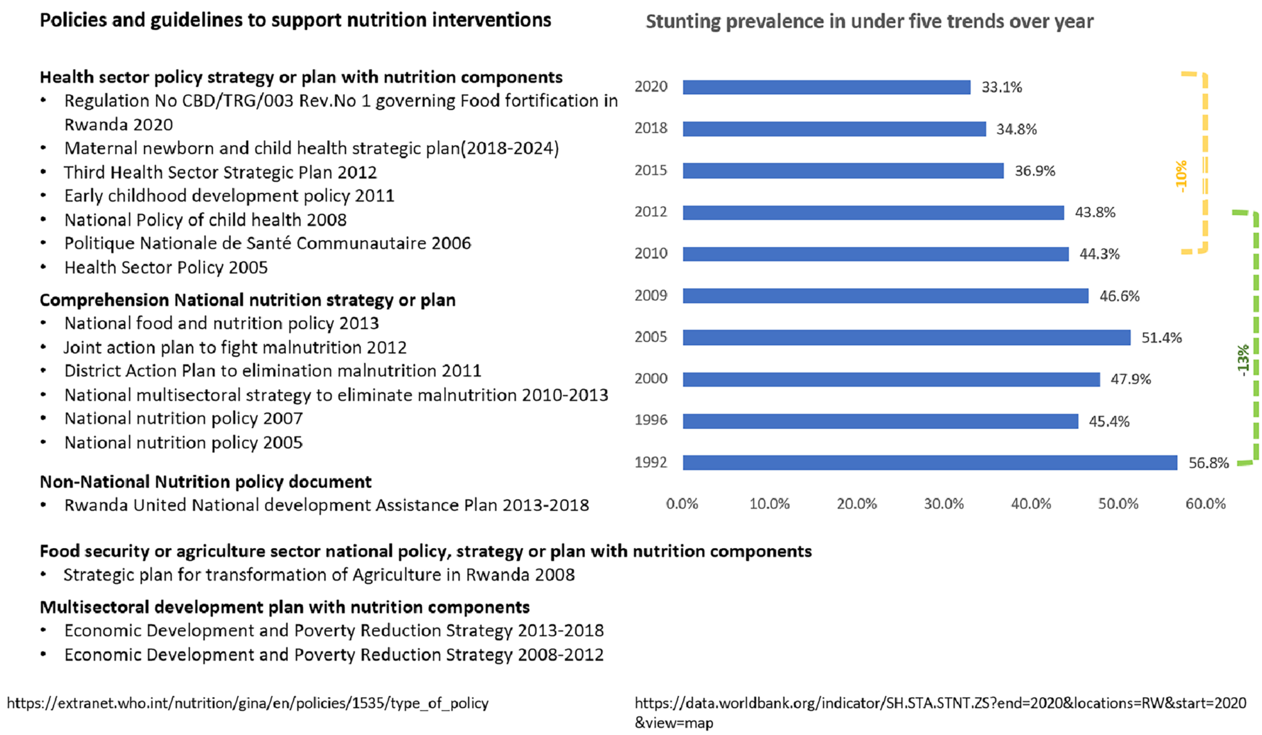

Fig. 1 The development of nutritional policies, strategies and national guidelines over time and the corresponding progress in reducing stunting among children under five in Rwanda between 1992 and 2020

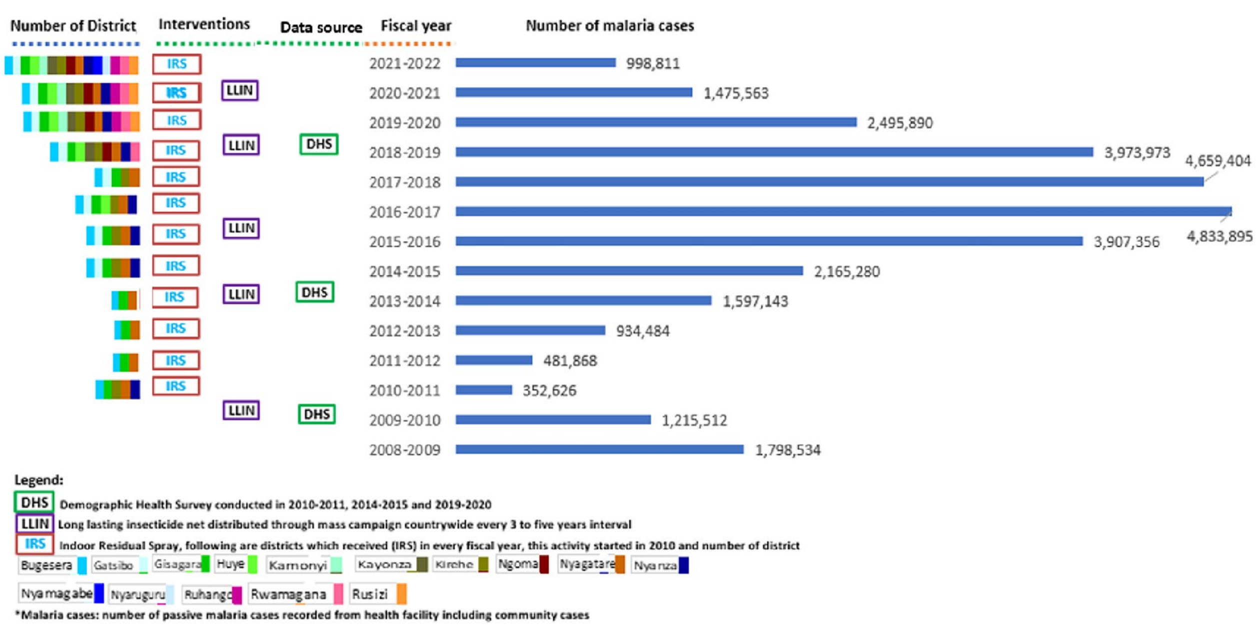

Fig. 2 Malaria interventions (LLINs and IRS) in Rwanda (2008–2022), highlighting implementation districts, data from DHS, and epidemiological impacts

deployed in different districts during this time. Following 2018, malaria cases gradually decreased, dropping to 998,811 in 2021–2022, likely due to the continuous implementation of these control measures.

Demographics

This study's analysis included 11,571 children under five with a 1:1 male-to-female sex ratio. Among the participants, approximatively one-third (34.8%) were aged between 0 and 23 months, while two-thirds (65.2%) were between 24 and 59 months. Regarding economic status, 44.5% of the family wealth index is categorized as poorer. In every district except for the capital city, 81.6% of children under five reside in rural areas (Table 2). Despite the high urbanisation rate in the capital city, the study found that there are still variations in regions, with 89.1%, 75.8%, and 59.1% of children under five living in the urban area in the Kicukiro, Nyarugenge, and Gasabo districts of Kigali city, respectively (Table 3).

Table 2 Demographic and nutritional characteristics of children under five in Rwanda, DHS 2010, 2014–15, and 2019–20 (N = 10,411)

Variables	2010 n(%)	2015 n(%)	2020 n(%)	2010–2020 n(%)
Asymptomatic Malaria (N)	3739	3237	3435	10411
Negative	3698 (98.9)	3169 (97.9)	3404 (99.1)	10271 (98.7)
Positive	41 (1.1)	68.0 (2.1)	31 (0.9)	140 (1.3)
Stunting (N)	4077	3538	3809	11424
Normal	2297 (56.3)	2214 (62.6)	2537 (66.6)	7048 (61.7)
Stunted	1780 (43.7)	1324 (37.4)	1272 (33.4)	4376 (38.3)
Child's age (N)	3713	3222	3376	10311
0–23 months	1214 (32.7)	1171 (36.3)	1203 (35.6)	3588 (34.8)
24–59 months	2499 (67.3)	2051 (63.7)	2173 (64.4)	6723 (65.2)
Sex of child (N)	4133	3615	3821	11569
Male	2082 (50.4)	1848 (51.1)	1927 (50.4)	5857 (50.6)
Female	2051 (49.6)	1767 (48.9)	1894 (49.6)	5712 (49.4)
Residence (N)	4135	3615	3821	11571
Urban	555 (13.4)	783 (21.7)	796 (20.8)	2134 (18.4)
Rural	3580 (86.6)	2832 (78.3)	3025 (79.2)	9437 (81.6)
Regions (N)	4133	3615	3821	11569
Kigali city	441 (10.7)	418 (11.6)	432 (11.3)	1291 (11.2)
South	1032 (25)	926 (25.6)	878 (23)	2836 (24.5)
West	1007 (24.4)	887 (24.5)	977 (25.6)	2871 (24.8)
North	657 (15.9)	496 (13.7)	611 (16)	1764 (15.2)
East	996 (24.1)	888 (24.6)	923 (24.2)	2807 (24.3)
Wealth Index (N)	4135	3615	3821	11,571
Poor	1805 (43.7)	1643 (45.4)	1699 (44.5)	5147 (44.5)
Rich	2330 (56.3)	1972 (54.6)	2122 (55.5)	6424 (55.5)
Mother Education (N)	4135	3615	3821	11571
No Education	776 (18.8)	504 (13.9)	453 (11.9)	1733 (15.0)
Primary	2972 (71.9)	2605 (72.1)	2457 (64.3)	8034 (69.4)
Sec + High	387 (9.4)	506.0 (14.0)	911 (23.8)	1804 (15.6)
Underweight (Weight/Age SD) (N)	4077	3538	3811	11,426
Normal	3617 (88.7)	3221 (91.0)	3524 (92.5)	10,362 (90.7)
Underweight	460 (11.3)	317 (9.0)	287 (7.5)	1064 (9.3)
Wasting (Weight/Height SD) (N)	4077	3538	3809	11,424
Normal	3960 (97.1)	3460 (97.8)	3764 (98.8)	11,184 (97.9)
Wasted	117 (2.9)	78 (2.2)	45 (1.2)	240 (2.1)
Anemia (N)	3733	3230	3436	10,399
Anaemic	1428 (38.3)	1158 (35.9)	1257 (36.6)	3843 (37)
Not Anaemic	2305 (61.7)	2072 (64.1)	2179 (63.4)	6556 (63)

Table 3 Distribution of children under five by urban and rural areas across districts, Rwanda DHS 2010, 2014–15, and 2019–20 (N = 10,411)

District	Urban		Rural	
	Freq	%	Freq	%
Nyarugenge	319	75.8	102	24.2
Gasabo	275	59.1	190	40.9
Kicukiro	361	89.1	44	10.9
Nyanza	45	12.4	318	87.6
Gisagara	35	8.9	359	91.1
Nyaruguru	27	6.9	364	93.1
Huye	44	12.5	309	87.5
Nyamagabe	23	6.6	328	93.4
Ruhango	45	13.8	282	86.2
Muhanga	64	19.9	258	80.1
Kamonyi	51	15.2	284	84.8
Karongi	55	15.9	290	84.1
Rutsiro	37	8.3	409	91.7
Rubavu	111	24.6	341	75.4
Nyabihu	46	11.7	348	88.3
Ngororero	25	6.7	349	93.3
Rusizi	69	16.4	352	83.6
Nyamasheke	32	7.3	407	92.7
Rulindo	31	9.2	306	90.8
Gakenke	25	7.4	313	92.6
Musanze	73	19.6	299	80.4
Burera	26	7.2	337	92.8
Gicumbi	39	11.0	315	89.0
Rwamagana	42	11.0	339	89.0
Nyagatare	60	13.9	373	86.1
Gatsibo	33	8.1	373	91.9
Kayonza	35	8.8	361	91.2
Kirehe	25	6.6	353	93.4
Ngoma	40	10.5	340	89.5
Bugesera	40	9.2	393	90.8
Total	2133	18.4	9436	81.6

Regarding education, 69.4% of mothers attended primary school, followed by 15.6% who had secondary and a high school diploma, and 15% had no education (Table 2).

Malaria data

According to the DHS from 2010, 2015, and 2020, 1.1%, 2.1%, and 0.9% of under-five children had asymptomatic malaria, respectively (Table 2).

Nutritional data

During the three periods of the demographic and health survey (DHS), the prevalence of stunting (chronic malnutrition) in children under five years old decreased from 43.7% and 37.4% to 33.4% in 2010, 2015, and 2020, respectively. Additionally, the prevalence of wasting (acute malnutrition) declined steadily from 2.9% in 2010 to 2.2% in 2015 to 1.2% in 2020. There was also a slight reduction in the prevalence rate of underweight children (too thin for their age), reduced from 11.3% and 9% to 7.5% in 2010, 2015, and 2020, respectively (Table 2).

Risk factors for asymptomatic malaria

For the years 2010, 2015, and 2020, Tables 4, 5, and 6 provide summaries of the unadjusted and modified odds that were used to compare asymptomatic malaria episodes to nutritional conditions. In the 3 DHS surveys, age correlated with increased asymptomatic malaria cases in children over 24 months compared to children under 23 months (Tables 4, 5 and 6).

In 2010, children aged 24 months and above had a higher prevalence of asymptomatic malaria than those who were under 23 months old (AOR = 2.37, 95% CI 1.13–4.99). Regarding anaemia, children identified as anaemic had a higher prevalence than non-anaemic children (AOR = 7.56, 95% CI 3.43–16.68). Furthermore, regarding the household wealth index, individuals classified as rich had a lower malaria prevalence than those categorized as poor (AOR = 0.39, 95% CI 0.19–0.79). Specifically, regarding nutrition indicators, being underweight was associated with a higher malaria prevalence (AOR = 1.39, 95% CI 0.55–3.54), but it was not statistically significant. More details are provided in Table 4.

In 2015, children aged 24 months or more had a higher prevalence of malaria than the youngest (AOR = 3.34, 95% CI 1.76–6.31). The rich wealth index had a lower malaria prevalence than the poor (AOR = 0.33, 95% CI 0.17–0.62). Anaemia was highly correlated with malaria; the prevalence of malaria was higher in anaemic children (AOR = 8.17, 95% CI 4.36–15.31). Interestingly, iodine supplementation negatively correlated with asymptomatic malaria cases, according to the 2015 survey, with an OR of 0.40 and 95% CI (0.21–0.78). Concerning nutritional status, underweight children had more asymptomatic malaria than children with normal percentiles for their age and sex (AOR = 2.64, 95% CI 1.33–5.26), Table 5.

DHS 2020 was the only survey where stunting showed a relationship with asymptomatic malaria (AOR = 2.51; 95% CI 1.11–5.67). Similarly, to 2010 and 2015, malaria prevalence was higher in children aged 24 months or more (AOR = 2.51; 95% CI 1.06–5.96) and in children identified as anaemic (AOR = 6.28, 95% CI 2.66–14.85) and in underweight children (OR = 2.31, 95% CI 0.88–6.05). Besides the adjusted odds ratio, the association

Table 4 Association between asymptomatic malaria infection and nutritional status in 2010: Unadjusted and adjusted analyses (N = 3,739)

Risk factors	Asymptomatic malaria cases		Univariate	P value	Adjusted	P value
2010	**n/N**	**%**	**OR (95%CI)**		**OR (95%CI)**	
Total	41/3737	1.10				
Age (months)						
6–23 months	11/1195	0.92	1	0.44	1	0.023
24–59 months	30/2489	1.21	1.31 (0.66–2.63)		2.37 (1.13–4.99)	
Residence						
Urban	4/489	0.82	1	0.53	1	0.88
Rural	37/3248	1.14	1.39 (0.49–3.94)		0.93 (0.31–2.81)	
Maternal Education						
No education	11/709	1.55	1	0.23	1	0.57
Primary	27/2689	1.00	0.64 (0.32–1.30)		0.82 (0.39–1.68)	
Sec + High	3/339	0.88	0.57 (0.16–2.04)		0.73 (0.14–2.67)	
Anemia						
Not anemic	8/2303	0.35	1	< 0.001	1	< 0.001
Anemic	33/1426	2.31	6.79 (3.13–14.76)		7.56 (3.43–16.68)	
Wealth index						
Poor	27/1630	1.66	1	0.005	1	0.009
Rich	14/2107	0.66	0.39 (0.21–0.76)		0.39 (0.19–0.79)	
Stunting						
Normal	20/1978	1.01	1	0.65	1	0.57
Stunted	20/1718	1.16	1.15 (0.62–2.15)		0.82 (0.41–1.64)	
Underweight						
Normal	33/3260	1.01	1	0.27	1	0.49
Underweight	7/436	1.61	1.59 (0.70–3.63)		1.39 (0.55–3.54)	
Wasting						
Normal	39/3598	1.08	1	0.95	1	0.66
Wasted	1/98	1.02	0.9 (41.13–6.92)		0.62 (0.08–5.11)	

with underweight became non-significant after adjusting for confounding variables (Table 6).

Nutritional risk factors for asymptomatic malaria

As shown in Table 7, this study combined the three cross-sectional analyses in 2010, 2015, and 2020 to examine the association between nutritional factors and asymptomatic malaria in this study. Overall, results indicated that underweight was associated with an increased prevalence of asymptomatic malaria (AOR = 1.59 95% CI 1.14–2.95). Stunting was also associated with the prevalence of asymptomatic malaria, with an OR of 1.85 (95% CI 1.32–2.59) but this association was lost with the AOR.

As for individual DHS survey analysis, increasing age was associated with an increased prevalence of asymptomatic malaria (AOR = 2.72, 95% CI 1.78–4.16). Female gender and primary or advanced maternal education were not associated with an increased malaria prevalence. There was also a linear association with the wealth index, as malaria prevalence decreased with increasing wealth index from the poorest to the wealthiest children.

Discussion

Rwanda's efforts to eliminate malaria and improve nutrition faced significant setbacks in the early 1990s due to disruptions in healthcare services, increased disease burden, and widespread malnutrition [38]. However, over the past three decades, the country has rebuilt a resilient healthcare system through strong leadership, evidence-based strategies, and well-defined priorities. A desk review revealed that in 2000, Rwanda adopted a national decentralization policy to strengthen local healthcare systems as part of broader post-genocide reconstruction efforts. This policy aimed to enhance community engagement, customize services to local needs, and improve health outcomes. By empowering local authorities and communities to plan and implement interventions,

Table 5 Association between asymptomatic malaria infection and nutritional status in 2014–15: Unadjusted and adjusted analyses (N = 3237)

Risk factors	Asymptomatic malaria cases		Unadjusted	P value	Adjusted	P value
2014–2015	**n/N**	**%**	**OR (95%CI)**		**OR (95%CI)**	
Total	68/3237	2.10				
Age (months)						
6–23 months	13/1154	1.13	1	0.006	1	< 0.001
24–59 months	53/2043	2.59	2.34 (1.27–4.31)		3.34 (1.76–6.31)	
Residence						
Urban	4/682	0.59	1	0.004	1	0.20
Rural	64/2555	2.50	4.35 (1.58–12.00)		1.95 (0.68–5.64)	
Maternal education						
No education	15/466	3.22	1	0.010	1	0.50
Primary	50/2351	2.13	0.65 (0.36–1.17)		0.91 (0.49–1.70)	
Sec + High	3/420	0.71	0.22 (0.06–0.75)		0.59 (0.16–2.20)	
Anemia						
Not anemic	13/2068	0.63	1	< 0.001		< 0.001
Anemic	55/1158	4.75	7.88 (4.29–14.49)		8.17 (4.36–15.31)	
Wealth index						
Poor	53/1489	3.56	1	< 0.001	1	0.001
Rich	15/1748	0.86	0.23 (0.13–0.41)		0.33 (0.17–0.62)	
Underweight						
Normal	50/2886	1.73	1	< 0.001		0.006
Underweight	17/303	5.61	3.37 (1.9–5.9)		2.64 (1.33–5.26)	
Stunting						
Normal	31/1905	1.63	1	0.025	1	0.35
Stunted	36/1284	2.80	1.74 (1.07–2.83)		0.75 (0.42–1.36)	
Wasting						
Normal	66/3127	2.11	1	0.79	1	0.31
Wasted	1/62	1.61	0.76 (0.10–5.57)		0.34 (0.04–2.72)	
Iodine						
No iodine	11/239	4.60	1			
Iodine present	57/2991	1.91	0.40 (0.21–0.78)	0.007	0.52 (0.26–1.05)	0.071

Rwanda created a more responsive healthcare system, particularly in tackling malaria and malnutrition. Community Health Workers (CHWs) play a critical role in expanding healthcare access, delivering preventive and curative services at the household level, and reducing barriers related to gender, socioeconomic status, and geographic location. To further decentralize healthcare, the Ministry of Health redistributed trained personnel from the central level to districts, where district health officers oversee malaria control, nutrition programmes, and other health indicators. The fight against malnutrition in Rwanda is guided by evidence-based interventions addressing undernutrition, overnutrition, and micronutrient deficiencies. In 2020, the government established the National Child Development Agency (NCDA) with a mandate to eradicate malnutrition and stunted growth among children. One of its key initiatives is the 1000 Days Campaign, launched in 2013 in collaboration with stakeholders, focusing on reducing infant, child, and maternal mortality through improved antenatal and postnatal care, iron and folic acid supplementation, exclusive breastfeeding, complementary feeding, growth monitoring, and community-based nutrition education. Additionally, the government introduced sustainable nutrition programmes, such as Akarima Kigikoni (kitchen gardens) in 2014 to promote household vegetable production and Girinka (one cow per poor family) in 2006 to improve food security and combat malnutrition. The Health Sector Strategic Plan (2018–2024) emphasizes high-quality, accessible healthcare and prioritizes

Table 6 Association between asymptomatic malaria infection and nutritional status in 2019–20: Unadjusted and adjusted Analyses (N = 3,435)

Risk factors	Asymptomatic malaria cases		Unadjusted	P value	Adjusted	P value
2019–2020	n/N	%	OR (95%CI)		OR (95%CI)	
Total	31/3435	0.90				
Age (months)						
6–23 months	7/1199	0.58	1	0.14	1	0.039
24–59 months	24/2168	1.11	1.91 (0.82–4.44)		2.51 (1.06–5.96)	
Residence						
Urban	3/720	0.42	1	0.13	1	0.76
Rural	28/2715	1.03	2.49 (0.76–8.22)		1.29 (0.37–4.56)	
Maternal Education						
No education	9/410	2.20	1	0.008	1	0.26
Primary	18/2223	0.81	0.36 (0.16–0.82)		0.55 (0.24–1.25)	
Sec + High	4/802	0.50	0.22 (0.07–0.73)		0.57 (0.16–2.05)	
Anaemia						
Not anaemic	7/2179	0.32	1	< 0.001		< 0.001
Anaemic	24/1256	1.91	6.04 (2.59–14.06)		6.28 (2.66–14.85)	
Wealth index						
Poor	23/1538	1.50	1	0.090	1	0.080
Rich	8/1897	0.42	0.28 (0.12–0.6)		0.45 (0.19–1.08)	
Underweight						
Normal	26/3167	0.82	1	0.001		0.69
Underweight	5/267	1.87	2.31 (0.88–6.05)		1.22 (0.44–3.39)	
Stunting						
Normal	10/2225	0.45	1	< 0.001	1	0.026
Stunted	21/1207	1.74	3.92 (1.84–8.36)		2.51 (1.11–5.67)	

preventive measures, including IRS, LLINs, and public health campaigns to improve healthcare-seeking behaviour. Through evidence-based policies and decision-making, Rwanda has increased domestic investment in health programmes and strengthened partnerships with local and international stakeholders to ensure affordable, sustainable healthcare services. Furthermore, the government continues to enhance community engagement by empowering CHWs to lead malaria control efforts, particularly in IRS implementation and early Test, Treat, and Track (TTT) strategies at the household level.

This analysis explored the relationship between asymptomatic malaria and nutritional indices adjusted by socio-demographic and economic factors and household parameters using the demographic and health surveys conducted in Rwanda in 2010, 2015, and 2020. It was observed that children under five who had an undernutrition index (stunted and underweight) had a statistically significant increased likelihood of developing asymptomatic malaria.

The findings from this study reveal a significant association between nutritional status and asymptomatic malaria in children under five reinforcing the importance of considering nutrition in malaria control efforts. Undernutrition weakens immune defenses, thereby increasing susceptibility to infections, including malaria. Similarly, malaria infections can exacerbate undernutrition by impairing appetite, inducing metabolic alterations, and increasing nutrient losses. A study conducted in Ethiopia also found that malaria was associated with stunting and wasting [39], further supporting the observed trends in Rwanda. While previous research has primarily focused on symptomatic malaria, this study highlights the importance of asymptomatic malaria, which contributes to sustained transmission and may hinder child growth and development.

While unadjusted analyses suggested a strong association between stunting and asymptomatic malaria, this association lost statistical significance in adjusted models. This suggests that socioeconomic factors such as maternal education, wealth index, and access to malaria prevention measures play a key role in shaping malaria risk among stunted children. Similar findings were reported by Gari et al. [2] where malaria was identified

Table 7 Pooled analysis of the association between asymptomatic malaria infection and nutritional status across three DHS Surveys (2010, 2014–15, 2019–20) (N = 10,411)

Risk factors	Asymptomatic malaria cases n/N	%	Unadjusted OR (95%CI)	P value	Adjusted OR (95%CI)	P value
Total	140/10409	1.34				
Age (months)						
6–23 months	31/3548	0.87	1	0.003	1	< 0.001
24–59 months	107/6700	1.60	1.84 (1.23–2.75)		2.72 (1.78–4.16)	
Year						
2010	41/3737	1.10	1	< 0.001	1	0.90
2015	68/3237	2.10	1.93 (1.31–2.85)		197 (1.31–2.96)	
2020	31/3435	0.90	0.82 (0.51–1.31)		1.01 (0.62–1.64)	
Region						
Kigali	3/1145	0.26	1	0.075	1	0.25
South	57/2563	2.22	8.66 (2.71–27.7)		4.01 (1.17–13,75)	
West	22/2581	0.85	3.27 (0.98–10.96)		1.55 (0.43–5.52)	
North	1/1600	0.06	0.24 (0.02–2.29)		0.13 (0.01–1.34)	
East	57/2520	2.26	8.81 (2.75–28.19)		4.68 (1.37–16.02)	
Residence						
Urban	11/1891	0.58	1	0.002	1	0.51
Rural	129/8518	1.51	2.63 (1.42–4.87)		1.04(0.53–2.04)	
Mother Education						
No education	35/1585	2.21	1	< 0.001	1	0.18
Primary	95/7263	1.31	0.59 (0.39–0.87)		0.76 (0.49–1.14)	
Sec + High	10/1561	0.64	0.29 (0.14–0.58)		0.65 (0.29–1.46)	
Sex						
Male	74/5291	1.40	1	0.63	1	0.98
Female	66/5118	1.29	0.92 (0.66–1.29)		0.99(0.70–1.42)	
Anaemia						
Not Anaemic	28/6550	0.43	1	< 0.001	1	< 0.001
Anaemic	112/3840	2.92	6.99 (4.62–10.61)		7.34 (4.79- 11.27)	
Wealth index						
Poor	103/4657	2.21	1	< 0.001	1	< 0.001
Rich	37/5752	0.64	0.29(0.19–0.42)		0.38 (0.24–0.58)	
Stunting(height/age)						
Normal	61/6108	1.00	1	< 0.001	1	0.840
Stunted	77/4209	1.83	1.85 (1.32–2.59)		1.15 (0.77–1.71)	
Underweight						
Normal	109/9313	1.17	1	< 0.001	1	0.012
Underweight	29/1006	2.88	2.51 (1.66–3.79)		1.59 (1.14–2.95)	
Wasting						
Normal	136/10120	1.34	1		1	
Wasted	2/198	1.01	0.75 (0.18–3.05)	0.69	0.49 (0.11–2.09)	0.278
Salt Iodine						
No iodine	13/525	2.48	1		1	
Iodine present	96/6442	1.49	0.59 (0.33–1.07)	0.083	0.66 (0.35–1.24)	0.29

as a risk factor for stunting and wasting, emphasizing the need to consider broader social determinants when analysing the interplay between malnutrition and malaria.

Globally, in 2015, malaria increased and was most prevalent in sub-Saharan Africa (WHO report [36, 37]). The same situation was observed in Rwanda, where malaria morbidity started progressively increasing from 2011 until it reached ten times the previous levels in 2016 [38]. Furthermore, these findings mirror the same trends in asymptomatic malaria cases, which increased by nearly 90.9% in 2015 compared to 2010. Moreover, this study confirmed the decline of asymptomatic malaria prevalence by 57.1% from 2015 to 2020. Mother's education increased over time, from 81 to 88% between 2010 and 2020, and this may be an explanation of the corresponding decrease in asymptomatic malaria, along with the improvements in malaria prevention and nutritional status [40, 41]. The prevalence of stunting has declined over the years, dropping from 43.7% in 2010 to 37.4% in 2015 and further decreasing to 33.4% in 2020. However, this is still higher than the prevalence of stunting in Eastern Africa, which is also significantly higher than the global average of 22.0% [42].

This study demonstrated that the incidence of asymptomatic malaria increased with age, particularly among older children aged 24 months and above, where there were 107 asymptomatic malaria cases out of 6700 in contrast to younger children below 24 months, who had 31 cases out of 3548. This is consistent with the gradually observed increased risk of exposure to mosquito bites compared to younger children who are more likely to sleep soundly under ITNs because they still share a bed with their mothers [30]. Moreover, children exposed to *Plasmodium falciparum* develop acquired immunity by producing antibodies against *P. falciparum*, which confer resistance to clinical malaria[31], thus increasing the prevalence of asymptomatic malaria episodes [11, 25].

According to the study's findings, asymptomatic malaria was more prevalent among children residing in the eastern and southern regions, which have a higher endemicity with 57 cases each out of around 2500, than in the City of Kigali. This might be due to perennial parasite exposure; children in areas with a high prevalence of malaria developed a strong immunity and typically appear with asymptomatic malaria [24, 25].

In 2010, 2015, and 2020, the odds ratios of asymptomatic malaria were lower in non-anaemic children, and this difference was statistically significant ($p < 0.001$), suggesting a potential association between non-anaemic children and lower rates of asymptomatic malaria. However, this does not imply a protective effect. Prior research indicates that malaria itself is a major cause of anaemia in children, and this association may be reflective of the impact of recurrent malaria infections on haemoglobin levels rather than a direct protective mechanism. Nonetheless, considering that prior studies have discovered a high association between anaemia and symptomatic malaria, this finding is not surprising. This indicates that malaria infection is the primary cause of anaemia in children. This study revealed a potential association between iodine supplementation and asymptomatic malaria. Considering that iodine is essential for growth, cognitive development, and overall good health [43, 44], this is comparable to these findings where children with the presence of iodine in salt consumed in their household tend to have a lower prevalence of malaria at 1.91% compared to 4.60% for children with no iodine; the odds ratio for children with iodine was 0.40 (OR = 0.4, 95% CI 0.21–0.78) in the year 2015. Moreover, it is important to mention that research examining the effects of acute and chronic malaria episodes on the release of thyroid hormones found that both acute and chronic infections showed inhibition of iodine hormone with no rebound effect, particularly in chronic malaria (i.e. with parasitaemia persistence) [45]. Therefore, further studies investigating the causal link between iodine supplementation and malaria protection are warranted to produce additional evidence.

This study had some limitations. First, the study used secondary data collected by routine surveillance rather than prospectively carrying out a longitudinal cohort study that more powerfully investigates exposure and outcome. Additionally, this study focused exclusively on asymptomatic malaria, as these infections often go undiagnosed and contribute to sustained malaria transmission. However, authors acknowledge that including symptomatic malaria cases would provide a more complete picture of how nutritional status influences malaria risk. Future research should examine both symptomatic and asymptomatic malaria cases using longitudinal cohort designs to establish stronger evidence on causal mechanisms.

Conclusion

In conclusion, the association between nutrition and malaria in Rwanda has been overlooked until now. This study highlights an association between nutritional status and asymptomatic malaria. Nevertheless, additional prospective longitudinal studies are required to conduct an in-depth analysis of the impact of nutrition on malaria outcomes. For instance, additional research should investigate the relationship between malaria protection and iodine supplementation. Given the complex relationship between nutrition and asymptomatic malaria in Rwandan children, future DHSs should thoroughly assess dietary determinants, particularly micronutrient parameters, to better understand their effects on infectious diseases such as malaria. Moreover, since other confounding factors seem to impact malaria infection, education, comprehensive monitoring, and evaluation of interventions such as maternal education programs and malaria preventive measures are required. Finally, targeted interventions should be directed by variations observed within regions in asymptomatic and symptomatic malaria cases.

Abbreviations

AOR	Adjusted odds ratio
CHW	Community health workers
CI	Confidence interval
DHS	Demographic and health surveys
HAZ	Height or length-for-Age Z-score
IRS	Indoor residual spraying
LLINs	Long-lasting insecticidal nets
NCDA	National child development agency
OR	Odds ratio
SDGc	Global sustainable development goals
SSA	Sub-Saharan Africa
VIF	Variance inflation factor
UNICEF	United Nations international children's emergency fund
WHO	World Health Organization
WAZ	Weight-for-Age Z-score
WHZ	Weight-for-Height or length Z-score

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Data availability
No datasets were generated or analysed during the current study.

Declarations

Ethics approval and consent to participate
Data was extracted from Rwanda's Demographical Health Survey (DHS), which is publicly available at www.measuredhs.com, after receiving written approval to use it from Macro.

Competing interests
A.E. and P.D.C. are inventors on patent applications dealing with the use of *A. muciniphila* and its components in the treatment of metabolic disorders. A. E. and P.D.C. are inventors on patent applications dealing with gut microbes in food reward dysregulations. A.E. is inventor on patent applications dealing with the use of bacteria metabolites in the prevention or treatment of respiratory viral infections P.D.C. was cofounder of The *Akkermansia company* SA and Enterosys. All other authors declare they have no competing interests.

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