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The Relationship Between Malaria Status in Under-five Children and Some Household Demographic, Socioeconomic and Environmental Factors Associated with the Disease in Sierra Leone

Mohamed Salieu Bah
Georgia State University

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By

Mohamed Salieu Bah

MSc in Project Management, University of Roehampton
BSc Biological Sciences, University of Sierra Leone

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Atlanta, GA 30303

Abstract

Background: Malaria in under-five children is a significant public health problem in sub-Saharan African countries with unprecedented mortality and morbidity. In Sierra Leone, the disease accounts for fourteen percent of under-five mortality and 95% of the population is at risk. The purpose of this study is to examine the relationship between malaria status in under-five children and household demographic, socioeconomic, and environmental risk factors potentially associated with the disease and to compare the test performance of rapid diagnostic test kit.

Methods: The study used cross-sectional data from the 2016 Sierra Leone Malaria Indicator Survey, which selected a nationally representative sample of 6,720 households in 336 clusters. Children aged 6–59 months in the selected households were tested for malaria using the rapid diagnostic test (RDT) and microscopy. Data were analyzed using descriptive statistics, bivariate and multivariate logistic regressions to identify risk factors associated with malaria at a 5% level of significance.

Results: The overall prevalence of malaria in under-five children was 52.67% and 40.05% using RDT and microscopy methods, respectively. RDT method was more sensitive than specific (85.52% vs. 69.23%, $p<0.0001$). The odds of malaria infection were significantly higher among older children aged 48–59 months (aOR= 3.28, CI: 2.61-4.13, $p<0.0001$), and children in the lowest wealth quintile (aOR= 5.47, CI: 2.89-10.37, $p<0.0001$). Other risk factors of malaria infection include children whose mothers/caregivers have attained primary educational level (aOR= 1.35, CI: 1.00-1.82, $p<0.05$), children living in houses built with unimproved wall materials (aOR= 0.79, CI: 0.64-0.97, $p<0.05$).

Conclusion: The findings of this study suggest that demographic and socioeconomic factors like age, wealth quintile, and educational levels of mothers/caregivers were predictors of malaria in under-five children in Sierra Leone.

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Mohamed Salieu Bah

Approved:

Dr. Lisa Casanova
Committee Chair

Dr. Ruiyan Luo
Committee Member

Dr. Heather Bradley
Committee Member

Date: April 24, 2020

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Authors Statement Page

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Mohamed Salieu Bah

Signature of Author

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CHAPTER I: INTRODUCTION

Malaria is one of the primary global health problems today, with an estimate of 219 million cases and more than 435,000 deaths in 2017 (WHO, 2018). As per WHO estimates, more than ninety percent of malaria cases and deaths occur in Africa, with sub-Saharan African countries recording higher rates (WHO, 2018). In 2017, under-five children accounted for 61% of malaria deaths globally (WHO, 2018). Deaths due to malaria in under-five children have significantly decreased over the last five years due to increase in resources to fight the disease. According to WHO (2015) resources to fight malaria increased from $960 million to $2.5 billion between 2005 and 2014 worldwide. Therefore, the disease is no longer the leading cause of death in this age group. However, malaria is still a considerable burden in children in Africa, causing an estimated 10 percent of all deaths of children on the continent.

In Sierra Leone, malaria is the leading cause of morbidity, with 95% of the population (6.7 million people) at risk, and it contributes to approximately 14% (131,383) of under-five mortality (MoHS, 2016). Globally, Sierra Leone accounted for 4% of malaria deaths in 2017 (WHO, 2018). Under-five children are amongst the most vulnerable groups to malaria infection due to a weak immunity to the disease (CDC, 2012). Malaria and poverty are closely linked. Malaria is concentrated in resource limited settings. Within these settings, the poorest and most marginalized are the ones that are severely affected. Such communities have the highest risks associated with malaria, and the least access to effective services for prevention, diagnosis, and treatment.

Malaria is a major threat to the socioeconomic development of Sierra Leoneans with an estimated 7-12 days lost on the average per episode of malaria. It imposes substantial costs to individuals, households and the government. Furthermore, severe malaria impairs children's learning and cognitive abilities by as much as 60%, consequently affecting the performance of Sierra Leone's universal primary and secondary education programs (MoHS, 2016).

To reduce malaria mortality and morbidity, the national program strategic plan targets a 40% decrease in the number of incident cases. Over the years, Sierra Leone made significant strides to successfully reduce the number of new malaria cases through supports from numerous partners and donors. Control strategies involved free distribution of long-lasting insecticide treated bed nets, indoor residual spraying and the removal of user fees in public and few private hospitals, making treatment free for malaria cases. However, despite these measures to reduce the burden of malaria, there is still a notable high number of children under five years dying from the disease (MoHS, 2016). Malaria accounts for 40% morbidity with over one million outpatient visits every year for under-five children. There are other underlying causes which exacerbates malaria morbidity in children such as pneumonia, diarrhea, and neonatal causes (MoHS, 2016).

The predictors of childhood malaria are not well understood in the context of Sierra Leone. Despite vulnerability and major consequences of malaria illness among under five, a good number of studies in Sierra Leone have focused on the knowledge attitudes and care-seeking behaviors, incidence, and prevalence of the disease at the population level. However, very little is known about household demographic, socioeconomic and environmental determinants that play a role in the incidence of febrile illnesses in under-five children in both rural and urban areas that are characterized by seasonal malaria transmission with frequent occurrence of epidemics. Malaria diagnosis for under-five kids in many parts of the country utilizes rapid test kits, which sometimes are not reliable due to test kit performance. Not a single study has been done in Sierra Leone to test the sensitivity and specificity of these malaria antigen detection kits.

Therefore, it is vital to understand the relationship between malaria status in under-five children and some household demographic, socio-economic, and environmental risk factors associated with the disease. The purpose of this study is to examine the relationship between malaria status in under-five children and household demographic, socioeconomic, and environmental risk factors potentially associated with the disease and to compare the test performance of RDT with microscopy.

CHAPTER II: LITERATURE REVIEW

Malaria remains a serious public health challenge in sub-Saharan Africa causing immense morbidity and mortality. It is a major barrier to socio-economic development and a significant contributor to poverty. This literature review investigated peer-review journals from PubMed, Google Scholar, Embase accessed through the Georgia State University library to understand the environmental, socioeconomic and demographic risks factors of malaria in under-five children. Key search terminologies included malaria, socioeconomic, demographic, environmental and household risk factors, malaria diagnostic tools, and malaria prevention strategies.

2.1 Demographic Factors

Factors like age, gender, place, and region of residence have all been characterized as significant predictors for malaria in children and adults as well as pregnant women. One study in Malawi looked at sociodemographic factors and their role in malaria morbidity in under-five children. The findings of this study revealed that the age of children is an independent predictor of malaria in 2012 and 2014 respectively (Zgambo, Mbakaya & Kalembo, 2017). The study showed that older children reported more malaria symptoms compared to younger ones. In Ghana, Nyarko and Cobblah (2014) also found that age was a strong risk factor for malaria in children. However, in a case-control study in Uganda Mpimbaza et al (2017) looked at the demographic, socioeconomic and geographic factors that could lead to severe malaria and delayed care-seeking in children. They found that an increase in the age of children was a protective factor against severe malaria.

Malaria affects both males and female; however, gender roles and dynamics give rise to various exposure patterns and vulnerabilities. For instance, in rural settings women are more likely to fetch water from nearby streams early in the morning and late in the evening exposing them to peak mosquito-biting times (Cotter et al., 2013). A study in Malaysia involving teenagers aged 15 years and above showed that gender and location (rural areas) are strong determinants of malaria (Ramdzan, Ismail & Mohd-Zanib, 2020). Malaria transmission is more prevalent in tropical and subtropical zones. The Ghana study showed that people residing in rural and the tropical regions of Ghana had more malaria compared to those living in urban and less tropical zones (Nyarko & Cobblah, 2014).

2.2 Household and Socioeconomic Factors

Household and socioeconomic factors could range from employment, household wealth index, educational level, housing characteristics such as materials used in construction, water and sanitation facilities, and electricity. The literature suggest that household income and educational level are major determinants of malaria. Households with low-income status have very few accesses to healthcare and hence disease burden is high in these settings. On the other hand, educational levels help improve health status due to compliance with prevention strategies. Chitunhu and Musenge (2015) looked at the direct and indirect factors of childhood malaria. They found that wealth quintile and educational level were directly or indirectly connected to malaria morbidity in under-five children (Chitunhu & Musenge, 2015). Mpimbaza et al (2017) also observed that having an employed caregiver/household head was a related factor to severe malaria. The study also showed that households with higher socioeconomic status and mothers with more than three children below 5 years are strongly associated with malaria.

Roberts and Mathew (2016) looked at risk factors of malaria in under-five children in Uganda. This study found that household factors such as main floor material, main wall material and availability of electricity in the household were closely related to malaria risk factors. The study also suggests that indoor residual spraying significantly reduces the risk of malaria n children. Children living in clusters with higher altitudes have a lower risk of malaria (Roberts & Mathews, 2016). Zgambo, Mbakaya, and Kalembo (2017) also found that households with a low income had higher chances of acquiring malaria. This was further shown in a follow-up study they did in 2014.

In terms of other social and economic factors that may well exacerbate malaria in children, is the presence of water and sanitation facilities at the household level. Yang et al (2020) observed malaria infections diagnosed by microscopy among individuals with different water and sanitation access in various sub-Saharan African countries revealed that the prevalence of malaria among the unprotected water users (22.6%) and piped water users (7.5%) were both significantly lower than the prevalence rate among the protected water users; however, this trend was not always consistent in all the surveys in these countries. The study further showed that children who do not have access to latrines were more likely to have malaria than children who used pit latrine toilets, whereas children who used flush toilets had a low tendency of malaria infection. They also found that malaria infections measured by RDTs in exposed and unexposed groups showed a significant reduction of malaria rates in households where there is protected water, pit latrines, piped water and flush toilets. On the other hand, households with unprotected water or use open defecation practices have higher risks of malaria when adjusted for potential confounders (Yang et al., 2020).

Studies have also shown that children living in poorly constructed houses have a greater chance of being bitten by mosquitos when compared to those who live in well-constructed houses. Ngadjeu et al (2020) studied the influence of house characteristics on mosquito distribution and malaria transmission in Yaounde, Cameroon. The study found that the risk of being bitten by mosquitoes was lower in houses constructed with cement walls or mix materials than in those constructed with mud or plank. This study also showed that parameters like the presence of holes on the walls, the number of windows, the presence of opened eaves or breeding sites near houses are strongly associated with increase indoor mosquito abundance.

In a study to determine the risk of malaria in under-five children in Nigeria, Morakinyo et al (2018) found that the type of housing (non-improved materials used in construction) is an essential risk factor for malaria in under-five children in Nigeria. Non-improved housing predicted malaria infection among under-fives in this study. The study also showed that children living in rural areas and poorest households were mostly affected by malaria (Morakinyo et al., 2018).

2.3 Environmental Factors

Environmental factors like altitude, rainfall, humidity temperature all play significant roles in the transmission cycle of malaria vectors. There is a positive relationship between malaria and warm tropical and subtropical climate (Arab, Jackson & Kongoli, 2014). Humidity and temperature are conducive environments for mosquitoes. Heavy rainfall creates stagnant pools and ditches which act as breeding sites for the mosquitoes and hence its population multiplies rapidly (Chua, 2012). Parasite growth within the host increases with an increase in temperature to complete the cycle (Jackson et al., 2015).

In Rwanda, Rudasingwa and Cho (2020) explored the determinants of persistent malaria in under-five children and found that malaria was more persistent in children who live in areas with sea level below 1700 meters and their household's income is very low and do not use insecticide-treated bed nets. This suggests that people living in poor households have a higher chance of malaria infections and that the disease decrease with an increase in altitude. Graves et al (2009) looked at individual, household and environmental risk factors for malaria infection in 3 regions in Ethiopia. They found that having insecticide-treated bed net and asset index were major risk factors of malaria. They also found that the richest households and households that were sprayed in the last 12 months before the survey had a lower risk of malaria infection. Maximum rainfall was also a strong predictor for malaria in the three regions. High altitude had a low risk of malaria prevalence.

In a similar study in Tanzania, Kaindoa et al (2018) observed the influence of physical characteristics of houses and surrounding environments on mosquito biting risk and malaria transmission. The results showed that the number of mosquitoes was significantly higher in houses with open eaves, grass roofs, Mud walls, and unscreened windows. The study further revealed that keeping chickens inside the house was also associated with a high number of mosquitoes.

2.4 Malaria Diagnostic Tools and Accuracy

The global impact of malaria has urged interest in developing prompt and effective diagnostic methods for resource-limited areas where there is a substantial burden on communities. Diagnosing malaria involves identifying the parasites through thick or thin blood smear films on a microscope or antigens on patient blood through rapid diagnostic tests. Malaria microscopy has and remains the gold standard for diagnosis. In endemic areas, malaria is a medical emergency and therefore requires urgent treatment. In low endemic areas, diagnosis through microscopy may pose significant challenges especially if the laboratory technicians are not well trained. However, the efficacy of diagnosis has often been the subject of debate among research scientists.

Nonetheless, both microscopy and RDTs offer significant steps for the diagnosis and treatment of patients. In a study to determine the performance of malaria test kits in India, Saha et al (2017) found that the sensitivity and specificity of rapid diagnostic test (RDT) kits (One Step Malaria Pf/Pv) and polymerase chain reaction (PCR) was high with RDT having a marginally higher sensitivity (94% vs. 90%) and specificity (99% vs. 95%). Sensitivity for microscopy was lower (63%) even though it showed high specificity when compared to RDT and PCR. Ashton et al (2010) also looked at the efficacy of three different types of RDT compared to microscopy (the gold standard) for malaria parasite detection in Ethiopia. The results showed that all three RDTs were sensitive in detecting Plasmodium falciparum at 85.6% and Plasmodium vivax at a range of 82.5 to 85%. CareStart showed slightly higher specificity (97.2%) for detecting p. vivax than ParaScreen and ICT Combo test kits. This study also revealed that health workers preferred Carestart and ParaScreen because of ease of labeling when compared to the ICT Combo. This study suggests that even though RDTs may not be the gold standard for malaria diagnosis, however, they make the work of clinicians easy especially in endemic countries where the urgent treatment of malaria-like symptoms is needed to avert fatalities. In a similar study done in Sierra Leone, Gerstl et al (2010) found that the sensitivity of CareStart was 99.4% and Paracheck 98.8%. CareStart showed higher specificity (96%) compared to Paracheck at 74.7%. With decreasing parasitemia, neither test showed any change in sensitivity.

Countries like Sierra Leone which is highly endemic for malaria, RDTs and microscopy are very important diagnostic tools for detecting and treating a patient. It is important to assess the accuracy and test performance for RDTs to ensure that malaria infections are not confused with other disease symptoms.

CHAPTER III: METHODS

3.1 Study Area

Sierra Leone is a country located on the western coast of Africa. Administratively, it is divided into four regions/provinces: the northern, southern, eastern, and western area, which includes the capital city of Freetown. The regions are further divided into 14 districts, which are subdivided into 152 chiefdoms. Across the 14 districts, there are 1,174 government-run peripheral health units which provides primary care. For secondary care, district hospitals provide technical support to the health units and serve as secondary level referral facilities for primary health care. Three major government hospitals located in Freetown and private hospitals and clinics provide specialist health services such as surgeries, obstetrics, gynecology, pediatrics, and internal medicine. Sierra Leone's climate is tropical with two distinct seasons: the dry season, which lasts from December to April, and the other months the rainy season.

3.2 Data Source

This study used data from the 2016 Sierra Leone Malaria Indicator Survey (SLMIS). The 2016 SLMIS is a cross-sectional household survey designed to provide estimates of demographic and health indicators related to malaria. The survey was conducted by the national malaria control program (NMCP) of the ministry of health and sanitation alongside the College of Medicine and Allied Health Sciences, University of Sierra Leone (COMAHS-USL), Statistics Sierra Leone (SSL), and Catholic Relief Services (CRS).

3.3 Sample Design

A sampling of study participants followed a two-stage sample design. This was done to ensure estimates of key indicators at national, regional, district, and urban/rural levels are understood. In the first stage, sampling involved the selection of clusters from the 2015 national population and housing census. A total of 336 clusters were selected with probability proportional to size from the 12,856 enumeration areas covered by the 2015 national census. Of these clusters, 237 were in rural areas and 99 in urban areas. Rural areas were oversampled within regions to produce the best estimates.

The second stage of sampling involved the systematic selection of households. A household listing process was done in May 2016, and households included in the survey were randomly selected from these lists. In each enumeration area, twenty households were selected for a total sample size of 6,720. Due to the unequal sample sizes in each district, the sample is not self-weighting at the national level. However, results shown in this study have been weighted to account for the complex sample design. All women between the ages of 15-49 years, residing permanently in the selected households and visitors who were present on the night before the start of the survey were enrolled. A detailed description of field procedures is described in the full report of the survey (NMCP et al., 2016). For this study, data was requested online from the Demographic and Health Survey website (www.dhsprogram.com) for approval.

3.4 Data Collection Procedure

The SLMIS data was collected between June and August 2016 through questionnaires on computer-assisted personal interviewing software programed on tablet computers. Blood samples were taken from children 6-59 months to test for malaria parasite (NMCP et al., 2016).

3.4.1 Malaria Rapid Diagnostic Test Procedure

A drop of blood from the finger/heel prick of the selected children was used for malaria rapid diagnostic test (RDT) using SD BIOLINE Malaria Ag P.f (HRP-II)™ (Standard Diagnostics, Inc.) to determine the histidine-rich protein II antigen of *Plasmodium falciparum*. Training was done for all field laboratory technicians to perform RDT based on the manufacturer's instruction. An applicator was used to draw up a small volume of blood, which was placed in the well of the testing device, and two drops of the buffer added to the other well. The result was read after 15 min. The results were then given to the parent/caregiver of the children and recorded in the biomarker questionnaire. Children with positive RDT were given malaria treatment based on the national malaria treatment guidelines if they were not on malaria treatment and had not had such treatment two weeks before the survey (NMCP et al., 2016).

3.4.2 Malaria Diagnosis by Microscopy

Microscopy using blood films was used as the gold standard for diagnosis. Both thick and thin blood films were prepared in the field using slides for each child. Every slide was tagged with a bar code and recorded in the biomarker questionnaire alongside the blood sample form from the field to the lab. Slides were dried and then transported in slide boxes. Thin smears were fixed using methanol at the end of each day. The slides were then stained with Giemsa and read. Thick smears were examined first to determine the presence of the malaria parasite. The thin smears for all positive thick smears were then examined to identify the malaria species present (NMCP et al., 2016). To ensure quality control, the slides were read by a second lab technician and followed by a third reviewer (laboratory director). Ten percent of all the slides were re-read by an independent quality control microscopist to affirm the quality of reading by the technicians.

3.5 Description of Variables

3.5.1 Dependent Variables

The outcome variable for this study was the presence or absence of malaria (binary outcome) as measured by one of two malaria diagnostic tests, RDT or microscopy. Due to the discrepancies between the results of the two tests, data were analyzed with separate models with the outcome in each model being the presence or absence of malaria infection as measured by each test. Because P. *falciparum* is the most common species in Sierra Leone, the RDT used in this study only detects the antigen of this specie.

3.5.2 Independent Variables

The independent variables for this study were grouped into demographic, household and socioeconomic and environmental. Demographic variables included the age of under-five children categorized in to <12, 12-23, 24-35, 36-47, and 48-59 months as used in a study by Zgambo, Mbakaya, and Kalembo, (2017), sex, region, and place of residence classified as rural or urban settings.

Household and socioeconomic variables included household wealth index classified as lowest, second, middle, fourth and richest, educational level of mothers/caregivers classified as no education, primary, secondary, sleeping under mosquito bed nets, materials used in the construction of the household was classified as either improved or unimproved based on the materials with which the floor, wall, and roof were built. Based on the work of Adebowale, Morakinyo and Ana (2017), the flooring materials were further categorized into either "Improved materials" which consist of cement, ceramic tiles, vinyl asphalt strips, parquet and polished wood or "Unimproved materials" which were made up of earth, sand, dung, rudimentary, wood planks, palm, bamboo, and others.

Similarly, the wall materials were categorized as either "Improved materials" (cement, stone with lime/cement, cement blocks and bricks) or "Unimproved materials" (no wall, cane/palm/trunks, dirt, rudimentary, bamboo with mud, stone with mud, uncovered adobe, plywood, and others. Roofing materials were categorized into "Improved materials" (Cement and roofing shingles) and "Unimproved Materials" (no roof, thatch/palm leaf, sod, rudimentary, rustic mat, palm/bamboo, wood planks, cardboard, wood, and others) (Adebowale, Morakinyo & Ana, 2017).

Also, source of drinking water and sanitation facilities were categorized as either improved or unimproved adapted from WHO and UNICEF drinking water, sanitation, and hygiene 2000-2017 progress report (2019). For the source of drinking water, improved sources consisted of water piped into dwelling/yard/plot, neighbor, public tap/standpipe, tube well/borehole, protected dug well, protected spring, rainwater, and bottled water. Unimproved source of water consisted of unprotected dug well or spring, water in tanker/truck/cart with a small tank, surface water, and other. Improved sanitation facilities were categorized as flush/pour-flush to a piped sewer system, flush/pour-flush to a septic tank, flush/pour-flush to a pit latrine, ventilated improved pit latrine, pit latrine with slab and composting toilet. Unimproved sanitation facilities consisted of open pit/pit latrine without a slab, bush/open field, bucket, flush/pour-flush not to a sewer/septic tank/pit latrine, flush to somewhere else, and others.

Environmental variables consisted of cluster altitude in meters above sea level categorized as 0-200, 201-400, and ≥401), and indoor residual spraying within the last 12 months before the study.

3.6 Data Analysis

Data were analyzed using statistical analysis software version 9.4 (SAS Institute Carey, North Carolina). Descriptive statistics were used in describing the distribution of children and the outcome variable malaria prevalence for both microscopy and RDT test results and the independent variables: age, gender, region, place of residence, wealth index, educational level, sleeping under mosquito bed net, housing characteristics (main materials used in construction of roof, wall & floor), source of drinking water, sanitation facilities, cluster altitude and indoor residual spraying in the last 12 months.

A bivariate logistic analysis was done for the outcome variable malaria microscopy because it is the gold standard for diagnosis. A multivariate logistic regression was also used to determine the risk factors of malaria among under-five children. All variables in the bivariate analysis were included in the multivariate analysis and adjusted for potential confounders. Due to the complex nature of the survey, all results were weighted to account for the design effect of the sample.

To compare the performance quality of the test outcome of the dependent variable as determined by RDT, a sensitivity and specificity analysis was done on the RDT using microscopy as the reference standard. All statistical analysis was tested using Rao-Scot chi-square test of significance at 5% level.

CHAPTER IV: RESULTS

4.1 Characteristics of Study Participants

A total of 7,677 children participated in the survey. Of these children, 6704 and 6715 were included in the analysis for malaria parasite using the RDT and microscopy test methods, respectively. A total of 962 children were excluded from the analysis because they did not fall within the age bracket (0-59 months) of this study. Overall, malaria prevalence for under-five children as determined by RDT and microscopy was 52.67% and 40.05% respectively.

4.2 Malaria Prevalence by Demographic Factors

Table 1 shows the distribution of under-five children tested for malaria parasites using RDT and microscopy methods. The percentage of children positive for malaria increased with increase in age for both RDT and microscopy ($p < 0.001$). In both RDT and microscopy, male children had slightly higher prevalence of malaria when compared to female, however, the difference was not significant. Under-five children residing in rural parts of the country and, more especially in the northern region, had a higher proportion of malaria for both RDT and microscopy ($p<0.0001$).

Table 1: Distribution of under-five children tested for malaria using RDT and microscopy and the association between test outcomes and selected demographic characteristics in Sierra Leone, 2016

Demographic Characteristics		Rapid Diagnostic Test		Microscopy	
		Positive N (%)	P-value**	Positive N (%)	P-value**
Age in Months					
	<12	277 (32.85)		209 (24.78)	
	12-23	593 (44.11)	<0.0001	408 (30.29)	<0.0001
	24-35	797 (57.11)		560 (40.03)	
	36-47	879 (56.34)		731 (46.74)	
	48-59	984 (63.10)		782 (50.06)	
Gender					
	Male	1789 (53.39)	0.3220	1354 (40.31)	0.7036
	Female	1741 (51.95)		1337 (39.80)	

Region					
	East	1046 (60.01)		742 (42.52)	
	North	1747 (65.11)	<0.0001	1433 (53.38)	<0.0001
	South	996 (60.23)		678 (40.97)	
	West	304 (19.38)		331 (20.94)	
Place of Residence					
	Urban	943 (32.66)	<0.0001	775 (26.73)	<0.0001
	Rural	3151 (66.14)		2409 (50.53)	

Note: Row percent used, **- Rao Scott chi square test statistic used at alpha = 0.05, N values are weighted.

4.3 Malaria Prevalence by Household and Socioeconomic Factors

Table 2 shows the distribution of under-five children tested for malaria parasite and the association between the test outcomes and selected household and socioeconomic factors. In both RDT and microscopy, malaria prevalence reduces with increasing wealth quintile and the educational level of mothers/caregivers ($p < 0.001$). For instance, children who belonged to the richest wealth quintile had a lower prevalence of malaria compared to those in the lowest and second wealth quintile. Similarly, children whose mothers/caregivers had higher educational levels had low malaria prevalence compared to those with no education or have attained primary education. Under-five children who have mosquito bed nets for sleeping had slightly higher malaria positives (RDT) compared to those who do not have mosquito bed nets for sleeping (table 2). Malaria microscopy test outcome shows no significant difference in prevalence between children who have mosquito bed net for sleeping and those who do not have (table 2).

In terms of drinking water source and toilet facilities, children who do not have improved sources had a higher proportion of malaria compared to those children living in households with an improved source of drinking water and sanitation facilities ($p< 0.0001$) for both RDT and microscopy.

Table 2: Distribution of under-five children tested for malaria using RDT and microscopy and the association between test outcomes and selected household and socioeconomic characteristics in Sierra Leone, 2016

Socioeconomic Characteristics	Rapid Diagnostic Test		Microscopy	
	Positive N (%)	P-value**	Positive N (%)	P-value**
Educational level of mothers/caregivers				
No Education	1692 (55.15)	<0.0001	1266 (41.23)	<0.0001
Primary	422 (57.57)		317 (43.28)	
Secondary	481 (38.12)		350 (27.72)	
Wealth Quintile				
Lowest	1114 (67.30)	<0.0001	876 (52.95)	<0.0001
Second	1131 (68.17)		880 (53.04)	
Middle	967 (62.93)		732 (47.59)	
Fourth	689 (45.52)		507 (33.41)	
Highest	193 (15.03)		188 (14.53)	
Has mosquito bed net for sleeping				
Yes	2643 (55.33)	0.0486	1984 (41.45)	0.9073
No	1451 (50.47)		1200 (41.66)	
Source of drinking water				
Improved	2523 (48.52)	<0.0001	1960 (37.57)	<0.0001
Unimproved	1570 (64.08)		1224 (49.98)	
Toilet facility				
Improved	1548 (42.14)	<0.0001	1226 (33.29)	<0.0001
Unimproved	2546 (64.00)		1957 (49.16)	

Note: Row percent used, **- Rao Scott chi square test statistic used at alpha = 0.05, N values are weighted.

4.4 Relationship Between Housing Characteristics and Malaria Diagnostic Test Results

As shown in table 3, the risk of malaria positive RDT and microscopy test results was significantly lower for children living in houses built with improved floor and wall material compared to those living in houses built with unimproved materials. For instance, children who tested positive for microscopy and living in houses built with improved floor and wall materials had a lower prevalence (32.81% and 35.11%) (table 3). Whereas children who live in houses built with unimproved floor and wall materials had a higher prevalence of malaria (49.68% and 48.42%), respectively. Similarly, children who tested positive for RDT and living in houses built with improved floor and wall material had a lower prevalence compared to children who live in houses built with unimproved floor and wall materials. However, there was no significant difference in terms of children who live in houses built with improved or unimproved roof materials for both tests (microscopy and RDT), as shown in table 3.

Table 3: Relationship between housing characteristics and tests status for under-five children in Sierra Leone, 2016

Housing Characteristics	Rapid Diagnostic Test		Microscopy	
	Positive N (%)	P-value**	Positive N (%)	P-value**
Floor materials				
Improved	1407 (42.02)	<0.0001	1102 (32.81)	<0.0001
Unimproved	2680 (64.18)		2076 (49.68)	
Wall material				
Improved	1750 (44.21)	<0.0001	1393 (35.11)	<0.0001
Unimproved	2344 (63.45)		1790 (48.42)	
Roof materials				
Improved	3534 (53.11)	0.2688	2762 (41.43)	0.1022
Unimproved	560 (56.13)		421 (42.20)	

Note: Row percent used, **- Rao Scott chi-square test statistic used at alpha = 0.05, N values are weighted.

4.5 Malaria Prevalence by Environmental Factors

Table 4 shows the distribution of under-five children tested for malaria parasites using RDT and microscopy and the association between the test outcomes of selected environmental factors. Between range of cluster altitudes, malaria was more prevalent in children who live altitudes of ≥401 meters above sea level (70.81%) compared with children who lives in altitudes below ≤200 meters (49.84%) above sea level for RDT. Children who live in households that were not sprayed against mosquitos in the past 12 months had a higher proportion of malaria RDT (53.85%) compared to those who live in dwellings that are sprayed against mosquitos (33.46%) (p< 0.0045).

Most of the children (1,942) who tested positive for malaria microscopy live in cluster altitudes ≤200 meters above sea level (38.58%) (table 4). Children who reside in households that were not sprayed against mosquitos in the past 12 months had a significantly higher proportion of malaria (microscopy) compared to children who live in households that were sprayed against mosquitos (p<0.0027) (table 4).

Table 4: Distribution of under-five children tested for malaria using RDT and microscopy and the association between test outcomes and selected environmental characteristics in Sierra Leone, 2016

Environmental Characteristics	Rapid Diagnostic Test		Microscopy	
	Positive N (%)	P-value**	Positive N (%)	P-value**
Cluster Altitude (in meters)				
≤200	2503 (49.84)	0.0017	1942 (38.58)	0.1515
201-400	732 (57.91)		550 (43.44)	
≥401	296 (70.81)		198 (47.48)	
Dwelling sprayed against mosquitoes in last 12 Months				
Yes	46 (33.46)	0.0045	30 (21.47)	0.0027
No	3038 (53.85)		2149 (41.92)	

Note: Row percent used, **- Rao Scott chi-square test statistic used at alpha = 0.05, N values are weighted.

4.6 Sensitivity and Specificity Analysis of the Rapid Diagnostic Test

Table 5 shows the diagnostic performance of the RDT compared with the microscopy test (the gold standard) for malaria diagnosis. The sensitivity of RDT was 85.52% and the specificity was 69.23% (P<0.0001). The accuracy of the RDT test was 75.99% with a higher positive and negative predictive values (table 5).

Table 5: Sensitivity, specificity, positive and negative predictive value for malaria RDT test in under-five children in Sierra Leone, 2016

	%	95%CI	p-value
Sensitivity	85.52	84.25-86.70	<0.0001
Specificity	69.23	67.86-70.57	
Positive Predictive Value	66.37	65.33-67.40	
Negative Predictive Value	87.06	86.06-88.01	
Accuracy	75.99	75.02-76.95	
Likelihood ratios			
Positive	2.78	2.65-2.19	
Negative	0.21	0.19-0.23	

4.7 Bivariate Logistic Regression Results for Malaria Microscopy

Table 6 shows the crude odds ratios for the relationship between malaria infection from microscopy and the independent variables. At the crude estimates, the odds of malaria infection were higher among all age groups with an increasing odd as with age (p<0.05). Similarly, when the age in months was run as a continuous variable (result not shown), the risk of malaria significantly increased (OR= 1.02, CI: 1.02-1.03, $p<0.0001$). The crude odds of malaria was also higher for under-five children living in rural areas (OR= 2.80, CI: 2.22-3.53, $p<0.0001$), Northern region of Sierra Leone (OR= 4.32, CI 2.99–6.25, $p<0.0001$), whose mothers/caregivers had attained primary level of education (OR= 1.99, CI: 1.50-2.64, $p<0.0001$), in households with the second wealth quintile (OR = 6.64, CI: 4.82–9.15, $p<0.0001$), whose households had not been sprayed against mosquitos in the past 12 months (OR=2.64, CI: 1.34–5.20, $p<0.05$). However, being a female is a protective factor against malaria infection (OR= 0.98, CI:0.88-1.09, $P>0.05$).

Additionally, an unimproved source of drinking water (OR= 1.66, CI: 1.40-1.97, $p<0.0001$) and an unimproved sanitation facility (OR= 1.94, CI: 1.62-2.31, $p<0.0001$) were strongly associated with a high risk of malaria infection in under-five children. Similarly, the quality of housing materials versus living in houses with unimproved floor materials (OR= 2.02, CI: 1.72–2.37, $p<0.0001$), unimproved wall materials (OR= 1.74, CI: 1.48–2.03, $p<0.0001$) were significantly linked with higher risks of malaria infection among under-five children. Cluster altitude in meters of the households was protective against malaria infection for under-five children living in ≤200 meters above sea level (OR= 0.41, CI: 0.31-0.56, $p<0.0001$) and 201- 400 meters above sea level (OR= 0.54, CI: 0.35-0.85, $p<0.05$). Similarly, when cluster altitude was run as a continuous variable (result not shown), the risk of malaria significantly increased (OR= 1.001, CI: 1.000-1.030, $p<0.05$).

Table 6: Crude Odds ratios of factors influencing malaria infection in under-five children using microscopy test results

Characteristics	Crude Estimates		
	OR	95%CI	p-value
Age in Months			
<12	1	-	-
12-23	1.32	1.06-1.64	0.0119
24-35	2.03	1.64-2.50	<0.0001
36-47	2.66	2.19-3.24	<0.0001
48-59	3.04	2.50-3.70	<0.0001
Gender			
Male	1	-	-
Female	0.98	0.88-1.09	0.7034
Residence			
Urban	1	-	-
Rural	2.80	2.22-3.53	<0.0001
Region			
West	1	-	-
East	2.79	1.89-4.13	<0.0001
North	4.32	2.99-6.25	<0.0001
South	2.62	1.80-3.82	<0.0001
Educational Level			
Secondary	1	-	-
Primary	1.99	1.50-2.64	<0.0001
No education	1.83	1.46-2.29	<0.0001
Wealth Quintile			
Highest	1	-	-
Fourth	2.95	2.12-4.11	<0.0001
Middle	5.34	3.92-7.27	<0.0001
Second	6.64	4.82-9.15	<0.0001
Lowest	6.62	4.75-9.21	<0.0001
Has Mosquito bed net for sleeping			
Yes	1	-	-
No	1.01	0.87-1.18	0.9073
Source of drinking water			
Improved	1	-	-
Unimproved	1.66	1.40-1.97	<0.0001
Sanitation Facility			
Improved	1	-	-
Unimproved	1.94	1.62-2.31	<0.0001
Main Floor Material			
Improved	1	-	-
Unimproved	2.02	1.72-2.37	<0.0001
Main Wall Material			
Improved	1	-	-
Unimproved	1.74	1.48-2.03	<0.0001
Main Roof Material			
Improved	1	-	-

Unimproved	1.03	0.85-1.26	0.7491
Cluster Altitude (in meters)			
≥401	1	-	-
201-400	0.54	0.35-0.85	0.0075
≤200	0.41	0.31-0.56	<0.0001
Dwelling sprayed against mosquitos in the last 12 months			
Yes	1	-	-
No	2.64	1.34-5.20	0.0052

4.8 Multivariate Logistic Regression Results for Malaria Microscopy

Table 7 shows the adjusted odds ratio for the factors associated with the prevalence of malaria infection (determined by microscopy) among under-five children. The adjusted estimates showed that age in months and wealth quintile are strong predictors of malaria infection in under-five children holding all other variables constant. As shown in table 6, the odds of malaria infection in children within the age group 48-59 months were three times higher (aOR= 3.28, CI: 2.61-4.13, p<0.0001) after adjusting for all other variables. Similarly, the odds of malaria infection were five times (aOR= 5.47, CI: 2.89-10.37, p<0.0001) higher for under-five children in the lowest wealth quintile compared to those children in the highest wealth index after adjusting for all other variables.

The likelihood of malaria infection increased about 35% (aOR= 1.35, CI: 1.00-1.82, p<0.05) for children whose mothers/caregivers have attained primary educational level compared to secondary level after adjusting for all other variables. Under-five children living in houses built with unimproved wall materials showed a protective effect of malaria infection compared to children living in houses built with improved wall materials (aOR= 0.79, CI: 0.64-0.97, p<0.05) after adjusting for other independent variables. The likelihood of malaria infection was 1.29 times (CI: 0.83-1.98, p>0.05) higher for under-five children living in cluster altitudes within the range of 201-400 meters above sea level compared to those living in cluster altitudes ≥401 above sea level after adjusting for other variables.

After adjusting for other independent variables, the source of drinking water, sanitation facilities, main floor, and roof materials, mosquito bed net for sleeping, gender, type of place of residence, region and indoor residual spraying in the last 12 months had a lower likelihood of malaria infection in under-five children (p>0.05).

Table 7: Adjusted odds ratios of factors influencing malaria infection in under-five children using microscopy test

Characteristics	Adjusted Estimates		
	aOR	95%CI	p-value
Age in Months			
<12	1	-	-
12-23	1.38	1.07-1.78	0.0139
24-35	2.28	1.77-2.94	<0.0001
36-47	3.01	2.39-3.79	<0.0001
48-59	3.28	2.61-4.13	<0.0001
Gender			
Male	1	-	-
Female	0.92	0.79-1.06	0.2421
Residence			
Urban	1	-	-
Rural	1.40	0.98-2.01	0.0664
Region			
West	1	-	-
East	0.95	0.59-1.53	0.8321
North	1.50	0.97-2.33	0.0704
South	0.92	0.58-1.46	0.7315
Educational Level			
Secondary	1	-	-
Primary	1.35	1.00-1.82	0.0497
No education	1.06	0.84-1.34	0.6110
Wealth Quintile			
Highest	1	-	-
Fourth	2.62	1.78-3.87	<0.0001
Middle	3.66	2.27-5.90	<0.0001
Second	5.11	2.84-9.18	<0.0001
Lowest	5.47	2.89-10.37	<0.0001
Has Mosquito bed net for sleeping			
Yes	1	-	-
No	1.14	0.95-1.36	0.1587
Source of drinking water			
Improved	1	-	-
Unimproved	0.92	0.74-1.14	0.4430
Sanitation Facility			
Improved	1	-	-
Unimproved	0.94	0.74-1.19	0.5868
Main Floor Material			
Improved	1	-	-

Unimproved	1.09	0.86-1.38	0.4746
Main Wall Material			
Improved	1	-	-
Unimproved	0.79	0.64-0.97	0.0276
Main Roof Material			
Improved	1	-	-
Unimproved	0.78	0.59-1.04	0.0850
Cluster Altitude (in meters)			
≥401	1	-	-
201-400	1.29	0.83-1.98	0.2566
≤200	1.18	0.79-1.80	0.4302
Dwelling sprayed against mosquitos in the last 12 months			
Yes	1	-	-
No	1.77	0.78-4.01	0.1717

CHAPTER V: DISCUSSION AND CONCLUSION

The objective of this study was to determine the relationship between malaria status in under-five children and some of the demographic, environmental, and socioeconomic risk factors associated with the disease as well as to compare malaria diagnostic test kits in Sierra Leone. Based on the findings of this study, the factors that are strongly associated with malaria in under-five children are age, wealth quintile of households, and educational level of mother/caregivers as determined by microscopy.

Research has shown that as a child gets older, the likelihood of malaria infection increases with age. After adjusting for all other independent variables in this study, the findings were consistent with studies done in Nigeria (Morakinyo, Balogun & Fagbamigbe, 2018), Uganda (Roberts & Mathews, 2016), and Tanzania (Winskill et al., 2011) where older children had a higher proportion of malaria as well as increased risk of infection. This finding could possibly be linked to two factors: maternal antibodies conferred to children in their first 12 months of life and inadequate protection of older children. According to Charnaud et al. (2016), the antibody immunoglobulin G, which has a half-life of six months and is actively transferred during pregnancy and the nadir occurs at 6 months of life explains the reason why malaria is low in children in their first 12 months compared to older children. Another reason is that children who are still being breastfed are more likely to be protected with lactoferrin and secretory IgA, which have all been shown to impede the growth of malaria parasite in vitro (Kasim et al., 2000). Another possible reason for this difference in malaria infection is the anopheline mosquito's preference to bite adults and older children than infants (Dobbs & Dent, 2016). In many sub-Saharan African settings, the supervision of younger children becomes harder for the parents, therefore, exposing them to risks of malaria and other communicable diseases. Mothers/caregivers are more likely to cover their infants' skin with clothing and wade off mosquitos. These protective activities are sometimes limited for older children who are often outside playing with their peers and hence exposed to mosquito bites. This study also found that male children had slightly higher malaria prevalence compared to females even though the difference was not significant. Like in many settings, male children are adventurous and often play outdoors hence being bitten by mosquitos.

Malaria is a disease that thrives in poor households. This study has shown that children who live in poor households had a higher prevalence of malaria and an increased risk of infection. These results support the findings of studies conducted in Ghana (Nyarko & Cobblah, 2014), Uganda (Mpimbaza et al., 2017), Nigeria (Morakinyo, Balogun & Fagbamigbe, 2018) and Malawi (Chitunhu and Musenge, 2015; Zgambo, Mbakaya & Kalembo, 2017). It is not surprising that children in the upper wealth quintile have a lower likelihood of malaria infection compared to those at the bottom of the wealth index. Research has shown that individuals in the upper wealth quintile are more likely to afford improved houses, are well educated, and know malaria prevention strategies compared to people at the bottom of the wealth index (Ye et al., 2006). People in higher wealth quintile are more likely to be living in urban settings where there are better health services and hence increased care-seeking behavior. The low-income population mainly reside in rural areas, where financial access to healthcare is lacking. The cost of transportation, consultation, and medicines at health centers may be unaffordable for some families; hence early care for infected children is hindered (Rudasingwa and Cho, 2020).

The findings of this study also showed that the educational level of mothers/caregivers play a significant role in malaria infection in under-five children. Tusting et al. (2013) observed that the probability of dying from malaria decreases with increasing educational level. This study confirmed the role of education in the risk of malaria infection, as the risk of malaria increased the level of education decreased for mothers/caregivers.

While other studies have shown that poor/unimproved materials used in the construction of the floor, wall, and roof of houses have increased risk of malaria (Wanzirah et al., 2015; Pinder et al., 2016), the findings here showed that children living in houses built with unimproved wall materials have a protective effect of malaria after adjusting for other variables. These other studies note how poor housing quality facilitates mosquito entry and, thus, the transmission of malaria. While a finished wall surface may not be related with a higher risk of malaria due to its ability to allow mosquito entry into a household, households with these unimproved materials may have additional characteristics reducing the increased risk of malaria. There was no association of malaria infection for houses built with unimproved floor and roof materials.

Environmental parameters like altitude also play an essential role in malaria transmission because they impact the life cycle and development of the parasite in the mosquito. Studies in Tanzania (Bodker et al., 2003) and Kenya (Omondi et al., 2017) have shown that malaria transmission decreases with increasing altitude. In this study, the crude estimate showed a significant protective effect for malaria infection in children who live in cluster altitudes between 0-400 meters above sea level. However, after adjusting for other variables, the risk of malaria infection was not significant.

The sensitivity and specificity of malaria RDT in this study were 85.52% and 69.23%, respectively, which is consistent with a study in Nigeria (Morakinyo, Balogun & Fagbamigbe, 2018) that evaluated the same test kit. The positive and negative likelihood ratios of malaria RDT in this study were 2.78 and 0.21, respectively, suggesting that the test outcome is associated with the disease. Some studies have shown the impact on the sensitivity of RDTs based on the histidine-rich protein II antigen with an inherent limitation of the device, gene mutation, and storage conditions (Wongsrichanalai et al., 2007; Mouatcho & Goldring, 2013). Interestingly, in this study, the RDT detected more malaria cases (52.67%) than the gold standard microscopy (40.05%) method. RDTs detect antigens, unlike microscopy, which detects parasite giving RDT an added advantage to diagnose malaria in individuals or communities with low levels of parasites below the threshold of microscopy diagnosis (Batwala, Magnussen & Nuwaha, 2010). It is worth noting that there is the possibility of false-positive RDT results, especially when parasites are cleared by anti-malarial drugs and antigens may remain in circulation.

Even though crude estimates for region; type of place of residence; mosquito bed net for sleeping; dwelling sprayed in the last 12 months; source of drinking water; sanitation facilities and primary floor materials were all significant risk factors, however, after adjusting for each of these variables, the risk of malaria infection in under-five children was insignificant. The lack of association between malaria microscopy status and these other variables may be due to sampling strategy (more clusters in rural areas) and other effects.

5.1 Public Health Practice and Policy Implications

The results of this study emphasize the need for increased efforts to reduce the burden of malaria in under-five children in Sierra Leone. Considering that older children spend a more significant part of the day playing outdoors, introducing government or donor-subsidized mosquito repellents can go a long way to protect children from mosquito bites. Even though IRS was not a significant predictor of malaria in children in this study, however, increasing coverage of long-acting organophosphate IRS should be one of the government's priority vector control interventions. IRS can have significant impacts in the fight against malaria as children can be protected from mosquito bites outside bedtime. Moreover, Sierra Leone can adopt strategies implemented in countries like Botswana that have made significant progress in controlling malaria in under-five children through high coverage of both insecticides treated bed nets and IRS.

The extent of poverty also presents a significant challenge in the efforts of malaria eradication efforts since more than a quarter of the population lives on less than $2.5 a day. As resources for malaria control are limited, it is essential to identify poor households in clusters that are most at risk through a collaborative effort with the ministry of social welfare's agenda to reduce poverty to guide the allocation of the limited resources and interventions effectively. Such an approach will not only help bolster livelihoods in disadvantaged communities, but it will also help improve the overall health condition of low-income families.

Complementing control measures with the education of appropriate and consistent use of mosquito bed nets as well as education of practicing safe living habits, such as reducing outdoor activities during peak biting hours of a mosquito, can go a long way in aiding malaria control efforts. When providing health education to mothers/caregivers, the ministry of health and its partners should emphasize the importance of younger and older children sleeping under mosquito bed nets every night.

Furthermore, this study highlights how RDTs overestimate the prevalence of malaria in under-five children compared to the microscopy test outcome. Overestimation of the burden of malaria in under-five children in the context of Sierra Leone may be both beneficial and counterproductive in terms of malaria control interventions. Sierra Leone healthcare system is not well equipped with personnel and tools to diagnose diseases in rural communities. RDTs offer a simple and ease of use to rapidly diagnose and treat children in health posts who may present high fevers in the absence of a laboratory technician. On the other hand, the overestimation of malaria prevalence by RDTs may exacerbate drug resistance in individuals who are given anti-malarial drugs for the wrong reasons. To help reduce malaria burden, especially in rural areas, the ministry of health should focus on interventions addressing the gap in human resources for health as well as increasing diagnostic capacity at peripheral levels. RDTs used at peripheral health units should be regularly evaluated to ensure that they meet standard test procedures for effective diagnosis.

Lastly, when coming up with policies, guidelines, and interventions to control malaria in under-five children in Sierra Leone, special attention should be paid to older children, needy families, educational strategies for primary caregivers, and diagnostic tools.

5.2 Strengths and Limitations of the Study

The strengths of this study are the fact that it utilized survey data from a national representative sample, which can be used to generalize the findings for under-five children in Sierra Leone. Secondly, the study findings provide an understanding of malaria prevalence and demographic, environmental, and socioeconomic factors that affect under-five children. Like many studies, the study design (cross-sectional) used in collecting data may not infer causal inferences. Even though the study was conducted in the peak of the rainy season when mosquito biting activities are high, the absence of temperature and rainfall data to assess climatic variations may have contributed to the difference in parasitological test outcomes for malaria.

Furthermore, entomological surveys, are essential to understand how the type and the behavior of Anopheles mosquitos affect malaria transmission and to assist in addressing confounding factors involving the various ecological niches of distinct species. Unfortunately, entomological surveys were not part of the SLMIS. It is worth noting that the possible effect of the association between wealth quintile and materials used in the construction of wall, roof and floor may be contradictory to the overall findings of this study and therefore needs further investigation. Finally, the discrepancies in the two diagnostic methods (RDT and microscopy) and how the sampling was done may be biased to some study participants is worthy of mentioning. Despite these limitations, the findings in this study will serve as a reference for future studies and help support malaria intervention programs targeting under-five children in Sierra Leone.

5.3 Conclusion

To the best of our knowledge, this is the first study that has attempted to explore the relationship between malaria status in under-five children and demographic, environmental, and socioeconomic factors associated with the disease in Sierra Leone. The results of this study have shown that demographic and socioeconomic factors like age, wealth quintile, and educational levels of mothers/caregivers are independent predictors of malaria in under-five children in Sierra Leone. The results of this study also showed that RDTs are a vital diagnostic tool, especially in endemic communities where the burden of malaria is high, and there are inadequate laboratory technicians to respond to febrile illnesses of under-five children efficiently. Longitudinal studies are required to evaluate the associations of type of place of residence, mosquito bed net for sleeping, dwelling sprayed in the last 12 months, source of drinking water, sanitation facilities, and main floor and roof materials with the prevalence of malaria, which was non-significant in this study. Interventions to increase mosquito bed nets, as well as in and outdoor residual spraying, will significantly help in the malaria eradication approaches currently undertaken by the ministry of health and its partners.

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