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Research Article

Factors Influencing Malaria Infection in Rwanda 2010: A Cross-Sectional Survey Study Using Generalized Structural Equation Modeling

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Abstract

Background: Malaria is one of the world's primary public health concerns. In Rwanda, malaria prevention has become a significant problem against the double-barreled burden of an overstretched health system and strained financial resources.

Methods: A cross-sectional survey study design was done with a primary outcome variable was an ordinal variable with three categories; no malaria, probable malaria, and confirmed malaria cases. Statistical analysis was done using survey ordinal logistic regression modeling adjusting for random effects for direct effects.

Results: The 11,865 participants had a mean age of 22 years, and two-thirds of the participants were females (67%). Household related variables (socioeconomic status, health insurance, age in years) showed a significant total effect on malaria infection. Socio-economic status had the most significant total effect, which was a sum of the direct and indirect effects influenced indirectly by education, health insurance and the number of rooms for sleeping in isolation.

Conclusion: Poverty is still the core issue to the morbidity patterns driving the malaria. Access to health facility and health insurance has a high positive impact on decreasing disease. A better understanding of the drivers of morbidity directly and/or indirectly can better target interventions to be more efficient in those affected areas.

Keywords: Generalized Structural Equation Modeling (G-SEM); Malaria Morbidity; Malaria Indicator Survey (MIS); Demographic and Health Survey (DHS)

Abbreviations

G-SEM: Generalized Structural Equation Modeling; MIS: Malaria Morbidity, Malaria Indicator Survey; DHS: Demographic and Health Survey; SES: Socioeconomic Status; ALMA: Infectious Disease, African Leaders Malaria Alliance; LLIN: Long-Lasting Insecticidal Nets; ACT: Artemisia Combination Therapy; NISR: National Indicator Survey of Rwanda; WHO: World Health Organization; FA: Factor Analysis; GDP: Gross Domestic Product; UN: United Nation.

Introduction

Malaria is a significantpublic health issue in the world [1]. Globally, it was estimated that there were 660,000 deaths due to malaria, of which a large proportion over 86% were in children (less than five years age) and older people (above sixty) [2]. It is a preventable and treatable infectious disease transmitted by mosquitoes, yet it kills more than one million people every year in sub-Saharan Africa.In sub-Saharan Africa, malaria is the leading cause of death in children less than five years of age and accounts for about 91% of deaths occurring in children (less than five years of age) and older people (over sixty) [1]. The African Leaders Malaria Alliance (ALMA), in collaboration with the nine countries (Angola, Cameroon, Chad, Congo, Gabon, Equatorial Guinea, Central African Republic, DR Congo, and Sao Tomé-et-Principe) developed an African Roadmap to eliminate malaria by 2030 [1]. According to the World Health Organization (WHO) country-specific statistics, 2.2 million inhabitants out of 11.5 million people are at risk of malaria in Rwanda [3,4].

Malaria is mesoendemic (area in which a disease incidence is sufficiently high) in the low-lands and hypoendemic (area in which a disease incidence is sufficiently low) in the highlands of Rwanda [5]. Globally, in endemic areas where transmission occurred in long regular seasons, infection rates were highest among children less than five years of age who had not yet established immunity to the disease, contrary to epidemic areas where malaria transmission took place in short seasons; malaria infections in all age categories were high [6]. Furthermore, a study conducted in Rwanda's Ruhuha region concluded that there was also an increased risk of malaria in older age groups during long regular malaria season [7]. The reason may be that older people did not sleep under treated bed nets than young ones. Another reason might be that older people stayed out longer than younger ones, making them more likely to be bitten by mosquitoes [8,9].

Historically, it is believed that the most deadly malaria species,

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Plasmodium falciparum is prevalent in sub-Saharan Africa [10]. Consequently, malaria is hard to control in Africa due to vector species' efficacy and the predominance of the most severe species Plasmodium falciparum [11]. The risk of malaria infection is high in developing countries' rural areas and can be attributed to poverty and low lifestyle [12]. Factors that play the significant role in disease risk include proximity to the vector breeding sites, age, socio-economic status, altitude, moderate use of control measures, low income, limited access to the health facility, illiteracy, land use near pools, and open houses [13-16].

A recent global report shows that due to good political commitment and better utilization of funding, 54% of the above reduction has been experienced in African countries (WHO regions) [17]. As is the case in other sub-Saharan countries, in Rwanda, the use of Long-Lasting Insecticidal Nets (LLIN), Indoor Residual Spraying (IRS), and treating malaria cases with Artemesinin-based combination therapy (ACT) had reduced malaria infection up to 50% [18,19]. Therefore, it has a significant influence on the health and socio-economic well-being of people. Therefore, this work focuses on determining the direct and indirect determinants of malaria morbidity in poorer/financially challenged households and at an individual level in Rwanda in 2010 using malaria indicator survey (MIS) data accessible from the Demographic and Health Survey (DHS) website.

Methodology

This study was conducted as a cross-sectional survey design. The dataset used in this work is known as the Malaria Indicator Survey (MIS) dataset of Rwanda, part of the Demographic and Health Surveys (DHS) 2010. The previous study collected the data elements on basic demographic and health indicators, malaria prevention, treatment, and morbidity. The study includes both males and females tested for malaria diagnosis (rapid malaria test and confirmatory blood smear test), either positive or negative results. This work was conducted in Rwanda,a Central African country located South of the equator between latitude 1°4' and 2°51' South and longitude 28°63' and 30°54' East. It has a surface area of 26,338 square kilometers and is bordered by Uganda to the North, Tanzania to the East, the Democratic Republic of the Congo to the West, and Burundi to the South. Landlocked, Rwanda lies 1,200 kilometers from the Indian Ocean and 2,000 kilometers from the Atlantic Ocean [20]. Rwanda is divided into five geographically-based provinces—North, South, East, West, and the City of Kigali, with the provinces, further subdivided into 30 districts, 416 sectors, 2,148 cells, and 14,837 villages [20].

Sampling in the previous study was done in two stages. In the first stage, 492 villages formed the clusters were selected with probability proportional to the village size. The village population size also indicates the number of households in the village. The mapping and listing of all households in the selected villages was done. The resulting list served as the sampling frame for the second stage of sample selection. All of the 492 clusters were set for the modeling as surveyed for the 2010 RDHS. The selected data contained 11,865 households who consented to participate in the study and completed the individual's questionnaires. Data for children less than five years of age were collected from their mothers' parents or legal guardians [20,21].

According to the Center for Disease Control (CDC) and World Health Organization case definition criteria, the malaria outcome variable for this study was defined. The CDC and WHO definition indicates three possible states of malaria infection [22,23].

1. No malaria
2. Probable or (symptomatic or asymptomatic) malaria infection
3. Confirmed malaria infection

Two types of tests were conducted on surveyed population (rapid malaria test and confirmatory blood smear laboratory test). Participants who showed a negative result in both the tests (rapid malaria test and confirmatory blood smear laboratory test) were put in the category of "No Malaria Cases."The participants who were not tested for confirmatory blood smear laboratory or either show negative test but showed positive in the rapid malaria test were considered as "Probable or symptomatic or asymptomatic Malaria Cases".

Those who have positive confirmatory blood smear laboratory tests, regardless of their results from rapid malaria test, either positive or negative, were considered as confirmed malaria cases. The independent variables were split into four categories: individual-level variables (education gain in years, age in years, social-economic status, health insurance, household-related variable (no of rooms for sleeping), ecological variables (cluster altitude in meters and region) and behavioral variables (has clean water facility for drinking, and sleep under bed nets). Factor analysis (FA) was used to derive socioeconomic status (SES) using indicators data from the 2010 Rwanda Demographic Health Survey (RDHS). Factor analysis is a useful tool for investigating variables relationships for complex concepts such as socio-economic status [24]. It allows researchers to explore that are not easily measured directly by collapsing many variables into a few interpretable underlying factors. The process to create socioeconomic status is shown in (Figure SI and SII).

Reiter P. in 2008 studied the effects of temperature on Malaria transmission. His study proposed that temperature, rainfall, and humidity cannot be considered in exclusion without considering humans' behavior, and humidity cannot be considered in exclusion without considering humans' behavior. Additional factors that influence the malaria infection directly and/or indirectly; household and individual level related variables (SES, age, education, and health insurance), behavioral variables (Clean water facility for drinking and sleep under bed net), ecological variables [Regions (north, east, west and south)] and cluster altitude in meters).This study considers all the direct and indirect factors with the inclusion of human behavior as suggested by Reiter P. in 2008 [25]. This work considers human behavior and related direct and indirect factors (mentioned above), which have not been considered in previous studies.

Conceptual modeling technique and variables are divided into three main categories; ecological, household and/or individual level, and behavioral variables in the analysis with the purpose that these determinative factors run through the standard set of either 'proximate direct or indirect variables that have an influence on malaria morbidity [26,27]. Variables are either endogenous (dependent variable) or exogenous (explanatory variable) or both,

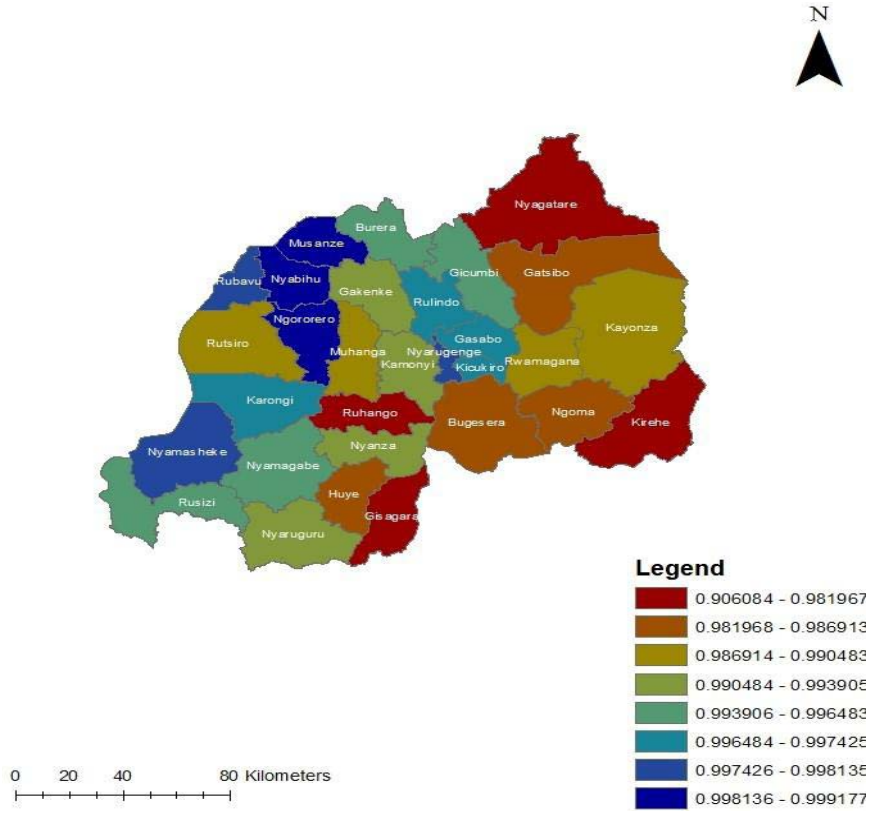

Figure I: Mean prevalence of malaria infection using direct and indirect G-SEM approach in Rwanda in 2010.

which can be modeled by using generalized structural equation models as shown in (Figure SI and SII). Details of these models provided in (Figure III and Figure IV).

Statistical analysis

Power computation was done using a STATA ado-file [28]. A sample prevalence of 2.1% comprised of 1.4% children and 0.7% adults adopted from the Rwanda Malaria Indicator Survey [3] and a 3% assumed population prevalence at an alpha level of 0.05. A design effect of 10 was used and intercluster correlation (ICC) of 0.071 with 492 clusters and average households per cluster of 115. Power was obtained at 89%.

Descriptive analysis was conducted using a survey chi-square test (Rao-Scott adjustment) adjusted for cluster effect. For categorical variables weighted percentages (proportion) with adjusted F-statistic are reported in (Table I). For continuous variables, mean and confidence interval are reported as shown in (Table I). Bivariate analysis was done using a survey chi-square test adjusting for cluster effect to establish the relationship between two categorical variables (such as malaria morbidity and gender). For the continuous explanatory variables such as age, survey ordinal univariate analysis adjusted for cluster effect was done. For bivariate analysis, odds ratio with p-value is reported in (Table II).

Multivariate analysis was done using step-wise forward selection survey ordinal logistic regression modeling adjusting for random effects and generalized structural equation modeling (G-SEM) to obtain total (direct and indirect) effects of malaria infection. The models were also tested using the ordinal regression diagnostics i.e., goodness of fit and multicollinearity, as those correlated with each other deleted from the final model. Variables were deleted from the model if they showed multicollinearity. Suest test was used to check the goodness of fit and see if a variable's addition did improve the model. It matches the estimates and (co)variance of the two models' coefficients simultaneously and gives an adjusted p-value.

Generalized Structural Equation modeling (G-SEM) was used to model direct and indirect effects on the malaria outcome. The conceptual framework is a good graphical display of the relationship between an explanatory and dependent variable to quantify the associations used for generalized structural equation modeling (G-SEM). G-SEM is a systematic way of evaluating hypotheses involving pathways analysis against multivariable data (29). Therefore, it is used to test and estimate causal relationships (direct and indirect effect) through statistical data and qualitative causal assumptions.

The selection was based on variables that were most significant in the final survey ordinal regression model. The model fit was assessed using the root mean square error of approximation (RMSEA) due to its sensitivity to the number of estimated model parameters and ability to handle large samples [30]. Studies show that an RMSEA below 0.8 leads to evidence of good fit [30]; hence the RMSEA of 0.03 from our G-SEM model was a good fit. All statistical analyses were carried out using Stata®13.1 (Copyright 1985–2013, StataCorp LP) Arc GIS was used for mapping the prevalence and variance of malaria infection in Rwanda.

Table I: Descriptive statistics survey weighted percentages of independent variables for Rwanda in 2010.

Independent variables					
Variable	**Category**	**Percentage of No Malaria Cases**	**Percentage of Probable Malaria Cases**	**Percentage of Definite Malaria Cases**	**Designed-based**
		(11,610, 97.67%)	**(137, 1.26%)**	**(118, 1.07%)**	**(Design-based F statistics and p-value)**
Sex	Male	20.07	0.27	0.36	F=7.46 (≤0.001)
	Female	77.42	0.99	0.69	
Education gain in Years	Mean (CI)*	2.64 (2.55, 2.74)	1.89 (1.38, 2.39)	1.38 (0.89, 1.86)	F=≤0.001
Age in years	Mean (CI)*	17.75 (17.53, 17.96)	14.84 (12.44, 17.23)	11.92 (9.80, 14.04)	F=≤0.001
Social Economic Status	Most Poor	43.1	0.71	0.62	F=5.39 (≤0.001)
	Poor	28.65	0.29	0.24	
	Least Poor	0.62	0.33	0.001	
Region	Kigali	10.44	0.0002	0.0003	F=14.55 (≤0.001)
	South	22.96	0.38	0.26	
	West	24.25	0.14	0.0008	
	North	16.23	0.0005	0.0004	
	East	23.8	0.66	0.64	
Place of Residence	Urban	13.66	0.0004	0.0005	F=11.59 (≤0.001)
	Rural	84.03	1.22	1	
Health Insurance	No	29.83	0.55	0.44	F=7.11 (≤0.001)
	Yes	67.86	0.71	0.62	
No of rooms	Mean(CI)*	2.30 (2.27, 2.35)	2.01 (1.79, 2.23)	2.04 (1.84, 2.24)	F=≤0.001
Clean water facility for drinking	No	92.39	1.21	1.02	F=11.02 (≤0.001)
	Yes	5.3	0.0005	0.0004	
Cluster altitude (M)	Mean (CI)*	1738.75 (1717.56, 1759.93)	1569.15 (1529.94, 1608.36)	1524.59 (1483.57, 1565.61)	F=≤0.001
Sleep Under treated Net	No	35.96	0.52	0.48	F=2.54 (≤0.001)
	Yes	61.73	0.74	0.57	

*CI: Confidence interval

This study was granted ethical approval by the University of the Witwatersrand's Human Research Ethics Committee (Medical) (Clearance Certificate No. M151040). Authorization to use the MIS data was obtained from the Measure DHS website. In the preliminary study, where the data was collected, verbal informed consent for testing children was obtained from the child's parent or guardian at the end of the household interview, and ethical clearances with the Rwanda authorities before the study started.

Results

The total number of individuals who participated in this study was 11,865 with a mean age and standard deviation of 22 ± 18 years. The number of individuals who were tested for malaria using malaria blood smear test and rapid malaria test, of whom 11,610 (97.67%) had no malaria cases, 137 (1.26%) had probable malaria cases, and 118 (1.07%) had definite malaria cases. The Eastern region had a weighted percentage of (0.64) of the total definite cases, the Southern region had (0.26) of the total definite cases, the Western region had (0.0008) of total definite cases, and the Northern and the Kigali region had like (0.0007) of total definite cases. A total weighted percentage of (1) of individuals having definite malaria cases were from rural areas, and (0.0005) was from urban areas. Female individuals were approximately (0.69), and male individuals were (0.36) had definitely weighted percentages of malaria cases of the total population.

Furthermore, Figure I and Figure II showed the mean prevalence and variance of malaria infection in Rwanda 2010 using the direct and indirect approach. Musanze, Nyabihu, and Ngororero regions had a greater prevalence of malaria infection in Rwanda in 2010 (Figure I). Nyagatara region had the, more significant malaria infection variance in Rwanda in 2010 (Figure II). The weighted mean and confidence interval of education gain in years and cluster altitudes were 1.38 (0.89, 1.86) and1524 (1483.57, 1565.61)in meters. The descriptive statistics survey-weighted percentages of independent variables with the significant test statistic of survey adjusted chi-square test are summarized in (Table I). Survey ordinal univariate analysis results, survey ordinal logistic regression modeling adjusting for random effects for random effects for direct effects and generalized structural equation modeling (G-SEM) to obtain (direct and indirect) effects of malaria infection are summarized in (Table II).

The direct effects from G-SEM are shown in (Table III). The arrows indicate pathways that were statistically directly significant. Household related variables (number of rooms for sleeping, socioeconomic status, health insurance, age in years, and education gain in years), has significantly shown a direct effect on malaria infection. Ecological variables (region and cluster altitude in meters)

Table II: Results of univariate, multivariate analysis adjusted for random effect, direct and indirect effect.

Independent variables					
Variable	**Category**	**Univariable analysis odds ratio (95% CI), p-value**	**Multivariable analysis adjusted for random effect, odds ratio (95% CI), p-value**	**G-SEM direct effect odds ratio (95% CI), p-value**	**G-SEM indirect effect odds ratio (95% CI), p-value**
Education gain in Years		0.89 (0.85, 0.95), ≤0.001	1.00 (0.99, 1.00), 0.96	0.98 (0.92, 1.04), 0.48	0.96 (0,94, 0.97), ≤0.001
Age in years		0.97 (0.96, 0.98), ≤0.001	0.99 (0.98, 0.99), ≤0.001	0.98 (0.97, 0.99), 0.03	
Social Economic Status	Most- Poor	1	1	1	
	Poor	0.70 (0.50, 0.98), 0.04	0.98 (0.97, 0.99), 0.04	0.64 (0.47, 0.85), 0.03	0.91 (0.85, 0.98), 0.02
	Least- Poor	0.43(0.26, 0.69), ≤0.001	0.97 (0.95, 0.98), ≤0.001	0.44 (0.29, 0.66), ≤0.001	
Region	Kigali	1	1	1	
	South	5.19 (1.77, 5.22), ≤0.001	1.02 (0.99, 1.04), 0.05	4.54 (2.03, 10.13), ≤0.001	
	West	1.78 (0.58, 5.44), 0.31	1.01 (0.99, 1.04), 0.20	2.82 (1.20, 6.67), 0.02	
	North	1.09 (0.34, 3.48), 0.88	1.01 (0.98, 1.03), 0.38	2.28 (0.84, 6.19), 0.10	
	East	10.24 (3.70, 8.34), ≤0.001	1.05 (1.03, 1.07), ≤0.001	5.45(2.56, 11.58), ≤0.001	
Health Insurance	No	1	1	1	
	Yes	0.60 (0.43, 0.80), ≤0.001	0.99 (0.98, 0.99), 0.04	0.79 (0.61, 1.02), 0.08	0.79 (0.61, 1.02), 0.07
No of rooms		0.72 (0.59, 0.88), ≤0.001	0.99 (0.98, 1.00), 0.15	0.87 (0.75, 1.00), 0.06	1.41 (1.21, 1.63), ≤0.001
Clean water facility for drinking	No	1	1	1	
	Yes	0.77 (0.66, 0.89), ≤0.001	0.98 (0.98, 1.00), 0.71	0.45 (0.21, 0.93), 0.03	
Cluster altitude (M)		0.99 (0.97, 0.99), ≤0.001	0.99 (0.98, 0.99), ≤0.001	0.99 (0.97, 0.98), ≤0.001	
Sleep Under treated Net	No	1	1	1	
	Yes	0.75 (0.56, 1.01), ≤0.001	0.98 (0.97, 0.99), 0.01	0.69 (0.54, 0.89), 0.01	
Random-effects Parameters Estimates For multivariable analysis					
S.D (hv002)			0.002694, (0.0006)*		
S.D (_cons)			0.059837, (0.0058)*		
S.D (Residual)			0.215894, (0.0016)*		
Inter-class correlation			0.071398**, (0.0130)*		

*Standard error

**Interclass correlation = $\frac{sd(hv002)^2 + sd(\_cons)^2}{sd(hv002)^2 + sd(\_cons)^2 + sd(residual)^2} = \frac{(0.002694)^2 + (0.05983)^2}{(0.002694)^2 + (0.05983)^2 + (0.215894)^2} = 0.071398$

and behavioral variables (sleep under a treated bed net and clean water facility for drinking) also significantly affected malaria infection.

Household-related variables, least low (a category of SES), and health insurance, were modeled as an exogenous variable, directly affecting malaria infection as shown in Table III adjusting for other household-level variables. The number of rooms for sleeping was modeled as an exogenous variable, directly impacted negatively on malaria infection as shown in Table III with total effect ¬ as shown in (Table III).

The indirect effects found from G-SEM are shown in (Table III). The connected arrows indicate indirect pathways that were statistically significant. Moreover, a variable like the number of rooms for sleeping was indirectly influenced by the least poor and the least poor were indirectly affected by education gain in years. Education gain in years also affected the health insurance, which showed a positive relationship as shown in (Table III).

Furthermore, when health insurance was treated as an endogenous variable, SES variable category "least poor" indirectly impacted malaria infection and had a protective effect as shown in (Table III). Education in years as an exogenous variable had no direct influence on malaria infection, but indirectly affected malaria infection through the least poor as shown in Table III and had a protective effect on health insurance as shown in (Table III).

When the number of rooms for sleeping was treated as an endogenous variable, SES variable category least poor was indirectly negatively impacted the malaria infection. However, it positively affected when the number of rooms for sleeping effect was direct, as shown in (Table III). The total effect is an accumulative value of direct and indirect effects of each respective variable. The results of the total effect are shown in (Table III). The least poor category showed a significant total effect, as shown in Table III Health insurance, as shown in (Table III). Education gain in years showed an indirect effect, and the resulting total effect was as shown in (Table III).

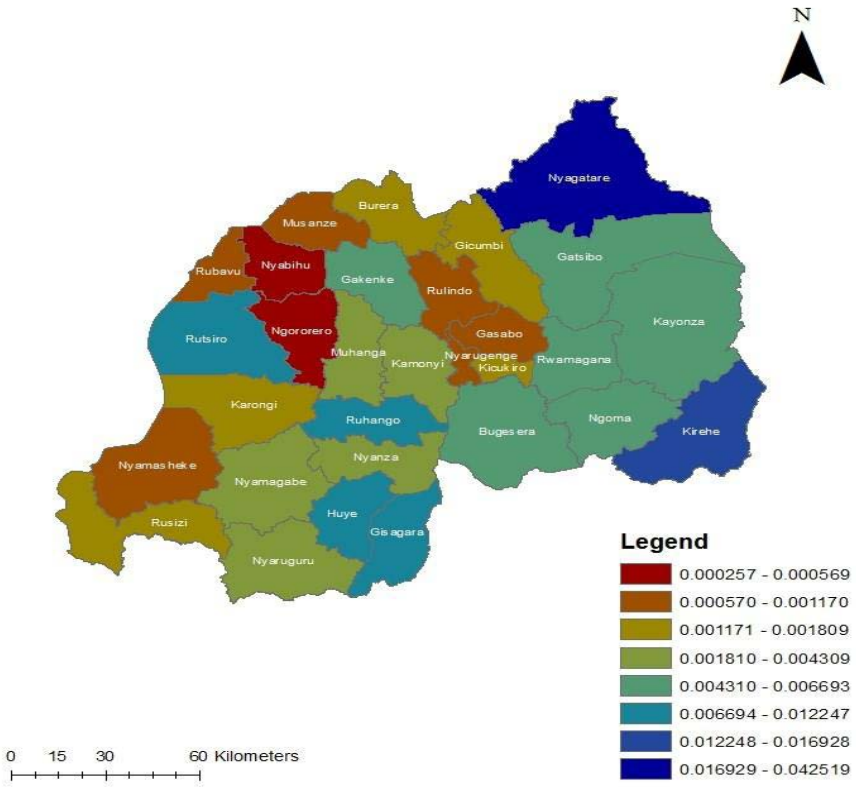

Figure II: Variance of malaria infection using direct and indirect G-SEM approach in Rwanda in 2010.

Generalized structural equation modeling (G-SEM) was based on statistically significant variables statistically significant variables in regression analyses chosen for G-SEM pathways as shown in (Figure III and Figure IV). Results were reported adjusting endogenous and exogenous factors and keeping other factors constant. The direct and indirect G-SEM technique showed positive and/or negative effects on the endogenous malaria infection. Exogenous variables were the least poor, health insurance, regions (north, east, west and south), and the number of rooms for sleeping in a household. The indirect effects were modeled on variables education in years, health insurance, least poor, and a number of rooms for sleeping. Figure III highlights the direct pathways of malaria infection (arrows directly linked to the brown square), and the indirect pathways were showed all possible routes of malaria in (Figure IV). In years, education gain indirectly impacted the malaria infection in two ways least poor (protective) and health insurance (a risk), as shown in (Figure IV). The Eastern region showed a greatest total effect on malaria infection as shown in (Table III), and cluster altitude in meters showed the least total effect on malaria infection as shown in "(Table III). The result of G-SEM showed both direct and indirect effects on endogenous variable malaria infection. The direct G-SEM model (Figure III) and indirect G-SEM model is (Figure IV) are shown. The endogenous variables, least poor, the number of rooms for sleeping, and health insurance are shown in (Figure IV).

Discussion

The current study revealed that malaria infection was influenced by various variables such as behavior, household condition, and ecological factors. In 2015, 214 million deaths were recorded due to malaria, and 91 % were in sub-Saharan Africa [31]. Social-economic status was a fundamental factor of malaria morbidity in several studies [32,33]. The studies also provided a positive malaria diagnosis.

As mentioned earlier, malaria is associated with poverty [32], the findings of this work complement the results of the previous studies on malaria morbidity. Previous studies have shown that low socioeconomic status increases malaria infection prevalence in developing countries [34]. According to the United Nations Accounts (UNA) central aggregated database 2015, Rwanda has low Gross Domestic Product (GDP) [35], which translates into higher malaria infections. This study also confirms the finding. It has also been indicated that malaria infection is a disease of developing countries, putting an additional burden on the healthcare facilities.

Logically the nutritional level is linked with GDP. Therefore, it is that poorer countries have inadequate resources to improve dietary levels resulting in low immunity against malaria disease [15]. Poor SES results in insufficient use of health-care facilities, therefore increasing the vulnerability of the population to the risk of malaria. Governments of the poorer countries need rational, optimum, and affordable policies to control malaria infection and treatment. This could be achieved by investing in research and data collection to investigate malaria trends to make effective and efficient policies and proper utilization of resources.

Regions (Kigali, south, north, east and west), place-of-residence (urban or rural), and cluster altitude in meters may be interrelated. However, fewer studies indicated an effect on malaria prevalence

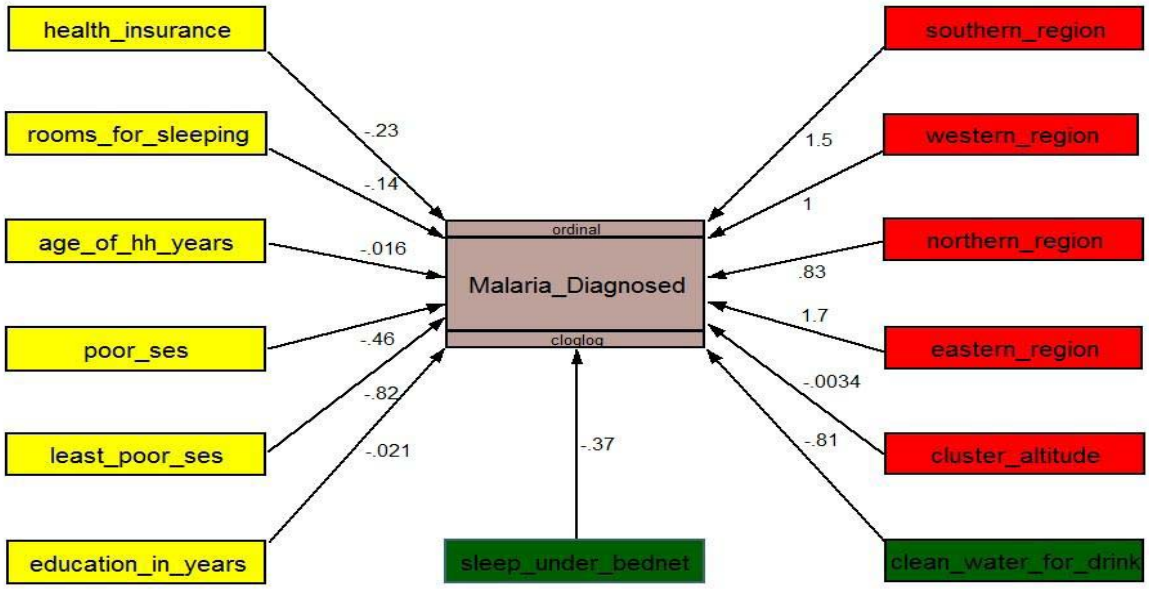

Figure III: The G-SEM pathway diagram shows direct coefficients from ordinal regression analysis of the effects of selected random predictor variables on malaria infection outcome variables resulting in children and adults in Rwanda in 2010. Key for variables names: individuals covered by health insurance (health_ insurance), number of rooms for sleeping in each house (rooms_for_sleeping), age of household members in years (age_of_hh_years), poor SES versus most poor SES (poor_ses), least poor SES versus most poor SES (least_poor_ses), education gain of each household member in years (education_in_years), number of household members sleep under a treated mosquito bed net (sleep_under_bednet), household members have a clean water excess for drinking (had_water_ excess), cluster altitude in meters (cluster altitude), the eastern region of Rwanda (eastern_region), the northern region of Rwanda (northern_region), the western region of Rwanda (western_region), the southern region of Rwanda (southern_region). Other: the arrows pointing from the exogenous (explanatory variables) to endogenous (dependent variable).

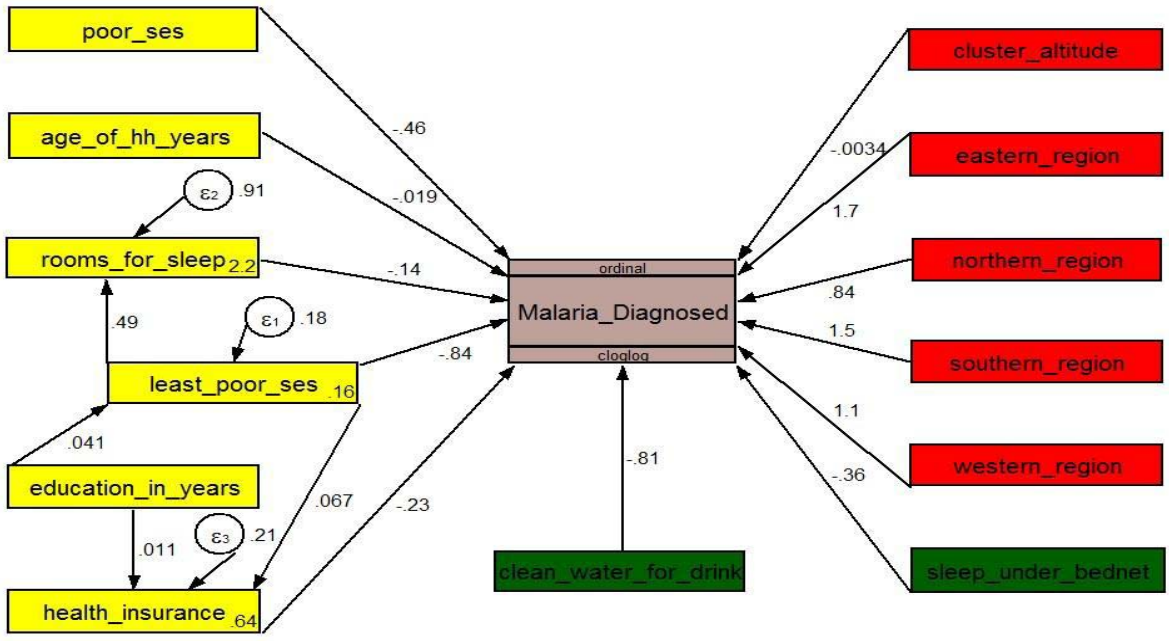

Figure IV: Diagram shows direct and indirect pathways and coefficients from G-SEM based ordinal regression analysis of the effects of selected random predictor variables on malaria infection outcome variable result in children and adults in Rwanda in 2010. Key for variables names: individuals covered by health insurance (health_insurance), number of rooms for sleeping in each house (rooms_for_sleeping), age of household members in years (age_of_hh_years), poor SES versus most poor SES (poor_ses), least poor SES versus most poor SES (least_poor_ses), education gain of each household member in years (education_in_years), number of household members sleep under a treated mosquito bed net (sleep_under_bednet), household members have a clean water excess for drinking (had_water_excess), cluster altitude in meters (cluster altitude), the eastern region of Rwanda (eastern_region), the northern region of Rwanda (northern_region), the western region of Rwanda (western_region), the southern region of Rwanda (southern_region). Other: the arrows pointing from the exogenous (explanatory variables) to endogenous (dependent variable) and the error terms placed on all three endogenous variables.

Table III: Direct, indirect and total effects of Malaria infection in children in Rwanda 2010.

Variable Category	Direct Effect on Malaria infection in children Rwanda 2010				Indirect Effect on child Malaria infection	Total Effect on child Malaria infection
	Education	Least Poor	No. of Rooms	Malaria Diagnosis directs effect coef.		
Education in Years					-0.04074 (0.00836)*	-0.04074** (0.00836)*
Age in years				-0.01869(0.00479)*		-0.01869**(0.00479)*
Social Economic Status						
Poor				-0.46468(0.15131)*		
Least Poor	0.04114 (0.00056)*			-0.84267 (0.20614)*	-0.08464 (0.03717)*	-0.92720** (0.20212)*
Region						
South				1.52598(0.40979)*		1.52598**(0.40979)*
West				1.05460 (0.43893)*		1.05460** (0.43893)*
North				0.84064 (0.50849)*		0.84064** (0.50849)*
East				1.71304 (0.38413)*		1.71304** (0.38413)*
Cluster altitude in meters				-0.00337 (0.00044)*		-0.00337** (0.00044)*
Sleep Under treated Net				-0.36210 (0.13021)*		-0.36210** (0.13021)*
Health Insurance	0.01109 (0.00063)*	0.06660 (0.00472)*		-0.23371 (0.13173)*		-0.3580 **0.1396)*
Number of rooms for sleeping		0.48576 (0.00907)*		-0.14219 (0.07511)*		-0.23297**(0.131793)*
Clean water facility for drinking				-0.80843 (0.20614)*		-0.34357** (0.07566)*

*Standard error, ** Total effect, ** Total effects computed as the product along the related pathways of least poor, i.e. ((0.06660)*(-0.23371)) + ((0.48576)*(-0.23371)) + (--¬0.84267) = -0.92720 (0.20212)

dependence on altitude [36,38]. Researchers also revealed that individuals living in low altitude areas are more at risk than higher altitude areas [39]. In this work, altitude has shown a marginal reduction in malaria infection. A study conducted in Thailand concluded that school children could be a better source of anti-malaria education for the family members than disseminating messages by newsletters [40]. To achieve a significant reduction in malaria morbidity in Rwanda, there is a need to improve the awareness and education status of the targeted population [41]. Knowledge about malaria prevention might be conveyed in the community by the students, who facilitate the household and families by applying and following influence in the targeted settings.

In this study, Age has shown a significance (p-value = ≤0.001). Previous studies have shown that children over the age of five were less at risk of malaria infection [8,42]. In this work, an increase in age has shown a reduced tendency of malaria infection; hence it is less likely to have positive malaria diagnosis as the age increases. Existing literature also confirms that older people (above 50) have a lesser chance of malaria infection due to developed immunity. Use of treated bed net has shown significant effect (p-value = ≤0.001). This study shows that individuals, who sleep under a treated bed net, are less likely to have a positive malaria diagnosis test. It might be because they have a lesser chance of having direct contact with infected mosquitoes. Health insurance showed the marginal significance of p-value = 0.06. The study results show that people with health insurance are less likely to get malaria infection. It is possibly due to health-related companies or knowledge of disease provided by the health insurance companies. Health insurance companies also offer preventative methods to protect against malaria.

Participants who have is for drinking are less likely to contract malaria as shown with clean water facility for drinking and are less likely to contract malaria as shown with a significant p-value = 0.01. The possibility is that is that malaria is an infectious disease and contaminated water is a good habitat for mosquito. Therefore, participants who have a clean water supply for drinking may be protected/safe as compared who do not. The number of rooms for sleeping have shown significance (p-value = ≤0.001). Hence, people, who have more spaces for sleeping, are less likely to get malaria infection. The G-SEM's indirect pathways showed a significant association between SES and health insurance, education and health insurance, education and least poor, and between SES and number of room for sleeping level. G-SEM was used in this study to complement the results from the multiple variable analyses. The results showed that the multiple variable analysis and the G-SEM direct pathways show similar results. G-SEM can help in diagrammatically measuring the effects of the determinants of the outcome and this can assist in the analysis where the variables can be separated into those with a direct effect on the outcome and those with an indirect effect on the outcome. This will help explain better some factors that might not directly affect the outcome, and inform policy on adopting indirect and direct approaches to dealing with the malaria infection in children and adults.

Conclusions

This study shows the importance of socioeconomic status and the influence of education in the fight against malaria. To eliminate malaria morbidity in the population, it is important for the governments to empower the community economically, intellectually and ensure the health education and awareness is a part of the efforts

to fight the endemic. Access to health insurance has a positive impact on decreasing malaria infections. Therefore health insurance could be focused as a useful tool in the intervention strategy, especially in relatively high-income sectors, to significantly reduce infections. This will assist in the fight to eliminate malaria.

It is important to ensure that the resources are channeled to optimize prevention strategies that are put in place. Once the population is empowered, the preventative strategies can then be implemented successfully. If the population is educated, it can understand the strategy put in place and follow them successfully. Health authorities and Government have to have the latest knowledge of the determinant factors to plan preventive and curative malaria strategies. The analysis methods used in this work could help the health authorities make effective and efficient strategies against malaria. Hence public health awareness campaigns must be empowered to educate the masses and eliminate malaria morbidity. It is necessary to understand the direct and indirect factors of malaria morbidity so that effective monitoring and evaluation policies for malaria control can be formulated.

The poverty reduction will go a long way in the fight to eradicate malaria in Africa in particular and globally in general. Generalized structural equation modeling (G-SEM), Malaria morbidity, Malaria indicator survey (MIS), Demographic and health survey (DHS), Socioeconomic status (SES), Infectious disease, African Leaders Malaria Alliance (ALMA), Long-lasting insecticidal nets (LLIN), Artemisia combination therapy (ACT), National Indicator Survey of Rwanda (NISR), World Health Organization (WHO), Factor Analysis (FA), Gross Domestic Product (GDP), United Nation (UN).

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