보건학 석사학위논문

Determinants of the Prevalence of Malaria in Rwanda: Cross-sectional study using Rwanda Demographic and Health Survey 2014-2015

르완다에서 말라리아의 유병률에 결정 요인: 2014-2015 르완다 인구 통계 및 건강 조사 자료 바탕으로 횡단면 조사

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Abstract

Determinants of the Prevalence of Malaria in Rwanda: Cross-sectional study using Rwanda Demographic and Health Survey 2014-2015

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Background: Malaria has a considerable impact on the health of the populations of developing countries; indeed, the entire population of Rwanda is at risk of contracting the disease. Although various interventions to control malaria have been implemented in Rwanda, the incidence of malaria has increased since 2012.There is an interest in understanding factors driving it's persistence in Rwanda. This study aims at evaluating the effect of socio-economic and environmental factors, seasonality and the use of insecticide-treated mosquito nets (ITNs) on Malaria persistence in Rwanda.

Methods: We analysed data from the 2014–2015 Rwanda Demographic and Health Survey of 10891household's members composed of children under the age of 5 and women aged between 15-49. Bivariate analysis were performed between the outcome and each covariate including wealth, altitude, education level, place of residence, and use of ITNs generating percentages. We performed Chi-square test to compare malaria negatives and positives on each covariate. Significant variables were subjected to multiple regression analysis to evaluate factors that are significantly associated with Malaria at $p<0.05$. The analysis was performed in R x64 3.6 using survey library, adjusting for sample weights, stratification and clustering. QGIS3.8 was used to map geographical distribution of malaria cases.

Results: The lowest wealth category was associated with the incidence of malaria (AOR =1.55**,** 95% CI = (1.18-2.05) .Having a place of residence <1700 m above sea level (asl) and non-use of ITNs were significantly associated with the incidence of malaria (adjusted odds ratio [AOR] = 2.90, 95% confidence interval [95% CI] = 1.92–4.38 and AOR = 1.30, 95% CI = 1.04–1.61, respectively). Season and type of residence were not significantly associated with malaria prevalence while women had lower risk of contracting malaria than children.

Conclusion: Income level, Altitude <1700m above the sea level and non-use of mosquito nets were associated with prevalence of malaria. Thus, potential interventions in Low income people and areas at low altitudes should be taken into consideration when formulating malaria-control strategies, Also use of ITNs to control the spread of malaria should be emphasised.

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Keywords: Malaria, mosquito net, season, altitude, residence, wealth category

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1. INTRODUCTION

Malaria is a major threat to human health globally and is endemic to the tropics and subtropics. Because of its impact on public health, malaria has received much attention (Autino.B, 2012). Rwanda is a sub-Saharan African nation whose entire population is at risk of contracting malaria. In 2012, Rwanda was classified as a malaria-endemic country by the World Health Organisation (WHO) (Henninger, 2012), and 1.8 million and 443,000 children <5 years of age and pregnant women, respectively, developed the disease in 2016 (PMI, 2017). Of the 30 districts of Rwanda, 19 are prone to epidemics and malaria is endemic in 11. The western and northern regions of Rwanda (~63% of the country) are epidemic-prone, while other areas are categorised as endemic and stable malaria-transmission zones, with the major foci in the south-eastern and eastern regions (PMI, 2017).

Malaria is regarded as a disease of the poor; indeed, the economic status of affected populations is a challenge for malaria control programs (Enayati & Hemingway, 2010). Poverty is closely associated with malaria, and the risk of malaria is twofold greater in the poorest compared to the richest children in a community (Tusting et al., 2013). Poverty is associated with the incidence of malaria in Uganda (Tusting et al., 2016). People living with poverty and hunger do not understand the purpose of malaria control strategies rather than focusing on eliminating these factors. Therefore, information on the socioeconomic conditions of malaria-affected populations is needed to control the transmission. However, few studies have evaluated the socioeconomic factors related to the transmission of malaria in Rwanda.

The WHO recommends that all individuals at high risk of malaria should have access to and use long-lasting insecticidal nets (LLINs) (WHO, 2017). Policy makers have w idely adopted the use of ITNs as one of the most malaria vector control strategies. I TNs treated with synthetic pyrethyroid insecticides were associated with a decline in malaria morbidity and mortality in Kenya and Tanzania (Abdulla et al., 2001; Howard et al., 2000). ITNs showed to reduce malaria cases by 26% by a meta-analysis(Choi et al., 1995) Recently, most African countries has increased the coverage of ITNs distributing them at very low price or free of charge(WHO, 2015). Insecticide-treated nets (ITNs) act as an effective intervention for malaria transmission prevention by reducing the risks of being bitten by infective mosquitoes (Lengeler, 2004; Phillips-Howard et al., 2003). The use of mosquito nets was effective against *Plasmodium* spp. in Somalia (A. M. Noor et al., 2008). ITN protection efficacy and effectiveness on malaria protection have been shown by several studies in Kenya, Myanmar and Malawi (Lindblade et al., 2015; Okoyo et al., 2015; Smithuis et al., 2013). Strategies for controlling malaria, such as inse cticide-treated mosquito nets (ITNs), significantly reduced malaria transmission in Rwa nda from 2006 to 2008 (Bizimana, 2015). Although high coverage of ITNs has been achieved, a trend towards non-use of ITNs has been noted in the Eastern Province (R uyange et al., 2016). In contrast, little is known about the misuse or non-use of ITNs among the general population.

The effect of altitude and temperature on malaria is poorly understood, but the probability of transmission of malaria decreases with increasing altitude (Bodker et al., 2003). This is because the temperature at high altitudes is lower than that required for development of the malaria parasite and for the activity of insect vectors. In Rwanda, 95% of the population lives at 1,400–2,400 m asl. An increase in rainfall and night-time temperature from 1984 to 1987 led to the emergence of malaria at >1,700 m and a 33.4% increase in the number of cases (Loevinsohn, 1994). Information on the effect of altitude on the transmission of malaria and the local pattern of malaria transmission is essential for planning interventions. However, little is known about the effects of altitude and environmental factors on malaria transmission in Rwanda.

We evaluated the associations between the incidence of malaria and socioeconomic factors, altitude, place of residence, season, and non-use of ITNs. The results will facilitate the formulation of effective strategies to reduce and ultimately eliminate malaria in Rwanda.

2. METHODS AND PARTICIPANTS

2.1. Study area

Rwanda is a landlocked country located in East Africa few degrees from the south of the Equator, characterized by a green, mountainous landscape. Rwandan geography is mainly dominated by savanna in the eastern part and mountains in the western part of the country. Rwanda has numerous lakes. Its climate is temperate to tropical but the temperature is typically lower compared to equatorial due to Rwanda's high elevation. Rwanda has two dry seasons and two rainy seasons every year. Population density is among the highest in Africa and the majority of the population is young and predominantly lives in rural areas.

Figure 1 Rwanda location in Africa

This study was community-based and of a cross-sectional design. We analysed the data from the 2014–2015 Rwanda Demographic Health Survey (RDHS) by which sample selection adhered two-stage stratified cluster sampling technique. A representative sample of 10,891 household members was analysed in this study.

2.2. Baseline characteristics

The highest education level was recorded as uneducated, primary, secondary, or higher. Wealth was categorised as poorest, poorer, middle, richer, and richest. Ownership of mosquito nets was recorded as yes or no, and sleeping under an ITN was recorded as yes or no. The district and type of residence were recorded as rural or urban. Month was recorded as January, February, March, April, October, November, or December, as both the survey and the anthropometric measurements were conducted during these months.

2.3. Cross-sectional surveys

Among the study population of 54,905 persons, 11202 women 15–49 years of age and children <5 years of age were subjected to anthropometric measurements. Diagnostic tests of malaria, including blood smear and rapid diagnostic tests were conducted among eligible under 5 years children and women aged between 15-49) who agreed to malaria testing. Malaria testing were performed with non-reusable, Sterile and self-retractable lancets in order to collect blood specimen from women and children under the age of 5. In the case of Rapid diagnostic tests, a drop of blood was obtained by pricking the end of the finger. Survey supervisors collected Blood samples for two or three times a week, then transmit samples to Rwanda National Institute of Statistics for verification then microscopic examination were done at the Entomology Laboratory. The results were then after referred to the National Reference Laboratory/RBC (Rwanda Biomedical Center) for quality control and assurance.

Testing was conducted on a subsample of 50% of the households then 11202 persons got tested.The results of malaria rapid tests and blood-smear tests were recorded as positive or negative.

2.4. Seasonal pattern measurement

The RDHS 2014–2015 was conducted during January, February, March, April, October, and December; the amount of rainfall and the temperature varies among these months. We calculated the incidence of malaria in each of these months. The months were classified into rainy (March, April, November, and October) and dry (December, January, and February) seasons.

2.5. Altitude

As 95% of the population of Rwanda lives at 1,400–2,400 m asl, the 33.4% increase in the number of cases due to the increase in the minimum night-time temperature and rainfall from 1984 to 1987 led to the emergence of malaria at >1700 m asl (Loevinsohn, 1994). Thus, altitude was classified as <1700 or ≥1700 m asl.

2.6. Analytical principle and methods

2.6.1. Descriptive statistics

Descriptive statistics were performed with percentage to identify the distribution and use of mosquito nets by general characteristics, Using SVYBY from survey library in R x64 3.4.4, descriptive statistics were performed with Percentages, standard Errors with 95% Confidence intervals to assess the proportion of malaria cases per season and proportion of malaria at <1700 and ≥1700 m asl and income category using RDHS sample weights, adjusting for cluster survey design. The significance between and each covariate with malaria negatives and positives were analyzed using Chi-square test and significant variables were included in multiple regression analysis.

2.6.2. Regression analysis

Using SVYGLM form Survey library, multiple regression analysis was conducted to explore association between prevalence of malaria and altitude, use of mosquito nets, season, social economic factors (level of education, income level) and place of residence.The threshold for significance was set at $P < 0.05$, and results are presented as crude odds ratios (CORs) or adjusted odds ratios (AORs) and 95% CI. QGIS3.6 was used to map the prevalence of malaria detected using the rapid malaria test.

2.7. Ethic statement

The Institutional Review Board of Seoul National University approved this study (IRB No. E1902/002-003). In addition, reporting of findings adhered to the STROBE guidelines for cross-sectional studies.

3. RESULTS

3.1. Prevalence of malaria

Among the 11202 subjects tested, 311 subjects' results were missing remaining with **10,891** subjects that were included in final analysis. Among 10,891 subjects, 594 malaria cases were identified by the rapid malaria test, for a prevalence of 5.45. The prevalence of malaria was high in the southern and Eastern Provinces. Kirehe District in the Eastern Province had the highest prevalence of malaria (19.69%), followed by Ngoma and Nyanza Districts in the Southern Province (14.47% and 12.57% respectively). No single case was found in Burera district in Northern Province.

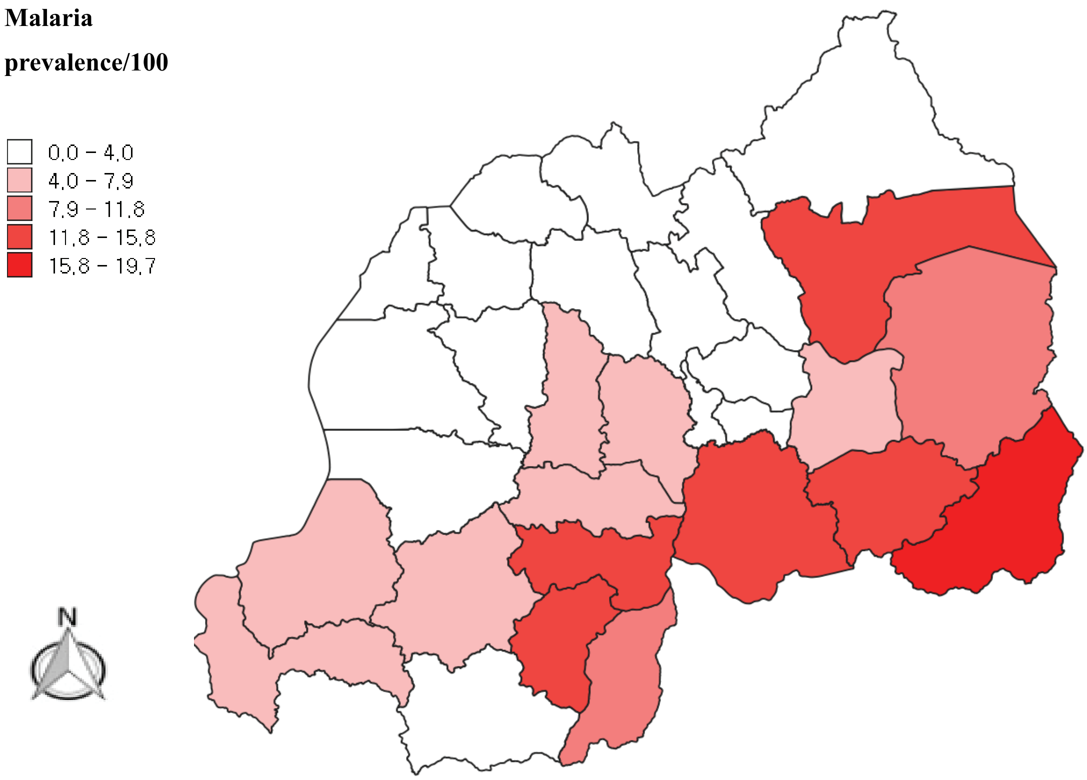

Figure 2 Geographic distribution of malaria cases confirmed by the rapid test

*Only women 15–49 years of age and children <5 years of age were subjected to rapid malaria testing.

3.2. Prevalence of malaria according to altitude

Blood smear and Rapid malaria tests were performed among household members living <1700 or ≥1700 m asl. For Rapid malaria tests, household members living at <1700m asl had 82.74% of all positive cases and only 12.26% for these living at≥1700m asl. For blood smear malaria test, Positives were 83.17% of all confirmed cases and 16.83 for others living at≥1700m asl.

Figure 3: Comparison between Altitude and malaria prevalence RDHS 2014-2015

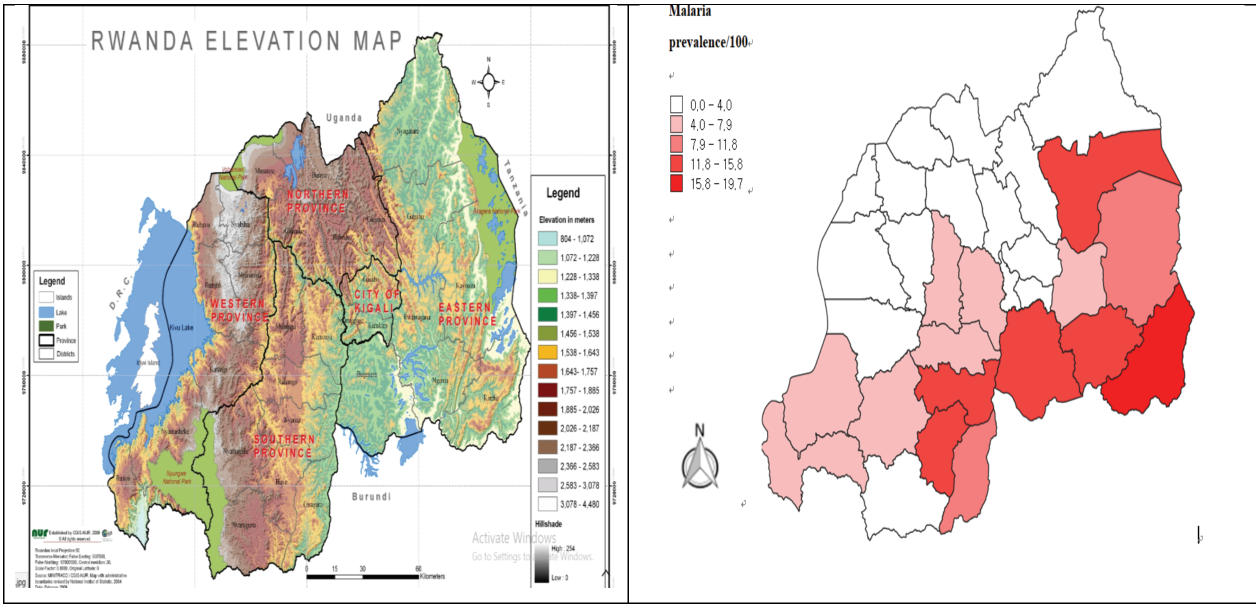

Figure 3 Comparison between Altitude and malaria prevalence RDHS 2014-2015

Left: Rwanda elevation map, Right: Malaria prevalence RDHS 2014-2015

3.2. Mosquito net ownership and utilisation

In Rwanda, 84.30% of the population own at least one mosquito net. However, only 66.25% of the population sleep under an ITN. Province of residence, education level, and wealth category influenced the ownership of ITNs. The frequency of ownership of ITNs was highest in Kigali (93.58%) and lowest in the Western Province (72.14%). Wealthier households were slightly more likely to own mosquito nets (94.09% and 68.93% in the richest and poorest wealth categories, respectively). 91% of the subjects with the highest education level owned mosquito nets, compared with 82.64% of the uneducated subjects. The use of ITNs was influenced by the same factors as their ownership. The percentage of the subjects who slept under an ITN on the night preceding the survey was highest in Kigali (78.67%) and lowest in the Western Province (55.44%) The proportion of urban residents who slept under an ITN the night before the survey was higher than that among rural residents with 75.24 and 63.46% respectively. The proportion of residents with a primary education level who slept under an ITN the night before the survey was 65.76% compared to 70.20 % for the subjects with the highest education level. The rate of ITN use increased with increasing wealth category. The frequency of ITN use in the poorest wealth category was 51.67%, compared to 78.73% for the richest wealth category.

Table 1 Frequency of ownership and use of mosquito nets

	Household members			
	N	**OWN ITN N (%)**	**USE ITN N (%)**	$x2(p)$
Total	**10891**	9182(**84.30**)	7217(**66.25**)	
Sex				**0.492**
*Boys	2139	1795(**83.92**)	1397(**65.31**)	
*Girls	2092	1772(**84.70**)	1402(**67.02**)	
*Women	6660	5615(**84.31**)	4418(**66.34**)	
Age				**<0.001**
*0-5	4231	3567(**84.31**)	2799(**66.15**)	
*15-29	3793	3176(**83.73**)	2319(**61.14**)	
*30-39	1800	1549(**86.06**)	1346(**74.78**)	
*40-49	1067	890(**83.41**)	753(**70.57**)	
Province				**<0.001**
*Kigali city	1402	1312(**93.58**)	1103(**78.67**)	
*South	2800	2442(**87.21**)	1960(**70.00**)	
*West	2473	1784(**72.14**)	1371(**55.44**)	
*North	1687	1376(**81.56**)	1014(**60.11**)	
*East	2529	2268(**89.68**)	1769(**69.95**)	
Residence				**<0.001**
*Urban	2593	2332(**89.93**)	1951(**75.24**)	
*Rural	8298	6850(**82.55**)	5266(**63.46**)	
Education level				**<0.05**
*No education	4873	4027(**82.64**)	3188(**65.42**)	
*Primary	4302	3597(**83.61**)	2829(**65.76**)	
*Secondary & Higher	1688	1536(**91.00**)	1185(**70.20**)	
*Missing	28	22(**78.57**)	15(**53.57**)	
Wealth Category				**<0.001**

*Poorest	2330	1606(**68.93**)	1204(**51.67**)	
*poorer	2146	1702(**79.31**)	1253(**58.39**)	
*Middle	1980	1712(**86.46**)	1340(**67.68**)	
*Richer	1896	1773(**93.51**)	1421(**74.95**)	
*Richest	2539	2389(**94.09**)	1999(**78.73**)	
Season				**0.0388**
*Dry	6935	5818(**83.89**)	4546(**65.55**)	
*Rainy	3956	3364(**85.04**)	2671(**67.52**)	
Altitude				**<0.001**
*<1700	6303	5719(**90.73**)	4630(**73.46**)	
*>1700	4588	3463(**75.48**)	2587(**56.39**)	

:: The sum of the percentages (%) may not be 100 due to rounding; $x2(p)$: Chi-Squared P value

Figure4: Rate of ITN usage per districts

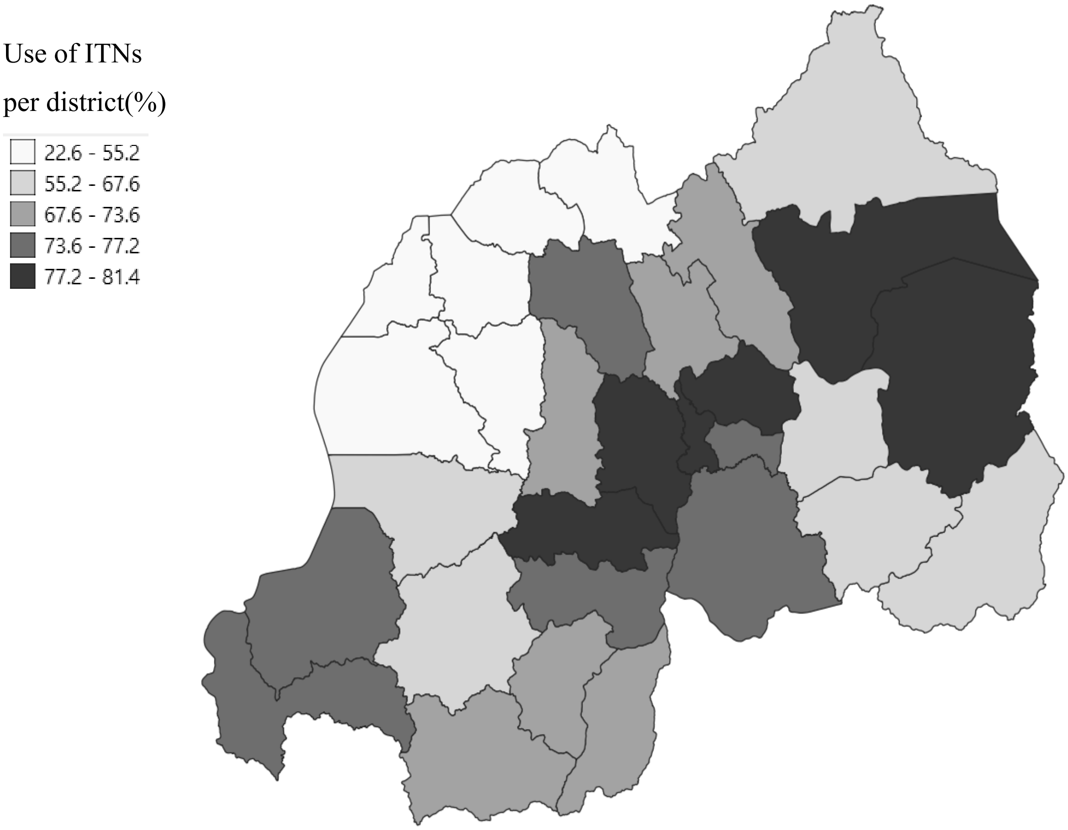

Figure 4 Rate of ITN usage per districts

Kigali city population has shown to use ITNs more than any other province in Rwanda whereas Northern Province showed a low rate of ITN usage.

Table 2 Background characteristics of study population according to malaria status

N=10891	Malaria Positive n = 594			Malaria Negative n = 10297			
Background Characteristics	Weighted Percentage	Standard error	95%CI	Weighted percentage	Standard error	95%CI	$x2(p)$
Sex							<0.001*
Boy	29.16	0.020	25.23-33.09	19.08	0.003	18.30-19.85	
Girl	26.79	0.019	23.02-30.57	19.16	0.004	18.37-19.94	
Women	44.03	0.023	39.51-48.56	61.78	0.004	39.51-48.56	
Age							0.997
0-5	55.96	0.023	51.43-60.48	38.24	0.004	37.31-39.16	
14-29	29.30	0.020	25.29-33.31	34.72	0.005	33.73-35.71	
30-39	8.80	0.011	6.47-11.13	16.89	0.003	16.18-17.60	
40-49	5.92	0.009	3.99-7.854	10.14	0.003	9.516-10.76	
Residence							<0.001*
Urban	5.97	0.014	3.22–8.72	18.87	0.009	17.10–20.64	
Rural	94.025	0.014	91.27–96.77	81.12	0.009	79.35–82.89	
Province							<0.001*
Kigali	2.569	0.007	1.080–4.058	12.86	0.014	9.937–15.78	
Southern	33.72	0.041	25.64–41.81	23.52	0.019	19.68–27.35	
Western	10.45	0.025	2.524–15.40	22.76	0.020	18.80–26.72	
Northern	1.899	0.006	0.578–3.220	16.58	0.017	13.10–20.06	
Eastern	51.34	0.045	42.35–60.34	24.26	0.021	20.14–28.38	
Wealth Quintile							<0.001*
Lowest	34.46	0.023	29.84–39.07	21.02	0.008	19.40–22.64	
Second	25.73	0.024	20.93–30.53	20.55	0.007	19.04–22.07	
Middle	21.01	0.019	17.22–24.79	18.79	0.006	17.48–20.11	
Fourth	13.53	0.017	10.50–17.01	18.29	0.007	16.87–19.71	

Highest	5.256	0.009	3.342–7.170	21.32	0.103	19.29–23.35	
Altitude							<0.001*
<1700	84.47	0.027	79.01–89.92	58.13	0.023	53.56–62.69	
>1700	15.52	0.027	10.07–20.98	41.86	0.023	37.30–46.43	
Educational level							
No Education	59.12	0.023	54.61–63.64	44.51	0.006	43.32–45.69	
Primary	33.50	0.020	[29.42–37.58	40.29	0.005	39.28–41.31	
Secondary & more	6.88	0.012	4.48–9.29	13.07	0.004	12.15–14.01	
Slept under Mosquito net							<0.001*
Yes	81.68	0.02	77.71–85.65	84.41	0.009	82.57–86.25	
No	18.31	0.02	14.34–22.28	15.58	0.009	13.74–17.42	
Season							<0.001*
Dry	61.66	0.022	59.68–68.41	64.04	0.022	59.68–68.41	
Rainy	38.33	0.044	29.66–47.01	35.95	0.022	31.58–40.31	

$x2(p)$: Chi-Squared P value

*The sum of the percentages may not be 100 due to rounding

Table 2 shows that rural areas had a high proportion of malaria-positive cases (94.025%, p>0.001). The Eastern Province accounted for more than half of all malaria cases in the country (51.34%, p<0.001), whereas Kigali had the lowest proportion of all the provinces in Rwanda, with only 2.569%. Those with the lowest income were more likely to have malaria, with 34.46% testing positive, whereas individuals with the highest income were the least likely to have malaria (5.256%). People with no education or living at <1700 m asl also had increased frequencies of malaria with, 59.12 and 84.47%, p<0.001 respectively.

3.3. Regression analysis of factors associated with the incidence of malaria in Rwanda

Non-use of ITNs was significantly associated with the incidence of malaria (AOR = 1.33, 95% CI = 1.07–1.64), as was living at <1700 m asl (AOR = 2.88, 95% CI = 1.90–4.36). The poorest and poorer wealth categories were associated with the incidence of malaria (AOR = 1.51; 95% CI = 1.15–1.98) and AOR = 1.14, 95% CI = 0.63–2.07, respectively). Season and type of residence were not associated with the incidence of malaria.

Table 3 Regression analysis of factors associated with the incidence of malaria.

Characteristics	CRUDE OR (95% CI)	ADJUSTED OR† (95% CI)
Sex		
Boys	Ref	Ref
Girls	0.92(0.72-1.16)	0.92(0.72-1.17)
Women	0.47(0.37-0.58)	**0.52(0.41-0.65)**
Age		
0-5	Ref	Ref
15-29	0.58(0.47 - 0.71)	**0.55(0.36-0.84)**
30-39	0.36(0.26 -0.49)	**0.33(0.22-0.51) *****
49-49	0.40(0.27-0.58)	**0.34(0.22-0.53) *****
Use of Mosquito nets		
Yes	Ref	Ref
No	1.31(1.07-1.61)	**1.30(1.04-1.61) *****
Altitude		
<1700m	3.92(2.70-5.69)	**2.90(1.92-4.38) *****
⩾1700m	Ref	Ref
Type of Residence		
Rural	Ref	Ref
Urban	0.27(0.17-0.45)	0.83(0.46-1.50)
Household wealth quintile		
Poorest	1.47(1.13-1.91)	**1.55(1.18-2.05) *****
Poorer	1.12(0.84-1.54)	1.19(0.90-1.59)
Middle	Ref	Ref
Richer	0.66(0.48-0.92)	**0.67(0.48-0.93) *****
Richest	0.22(0.15-0.33)	**0.36(0.22-0.61) *****
Province of residence		
Kigali city	0.43(0.22-0.87)	0.63(0.29-1.38)
Southern province	3.12(1.86-5.25)	**2.84(1.68-4.81)*****
Northern province	0.25(0.11-0.55)	**0.38(0.17-0.84) *****
Eastern province	4.61(2.74-7.74)	**3.09(1.76-5.42) *****
Western province	Ref	Ref
Education level		
No education	Ref	Ref
Primary education	0.63(0.51-0.76)	1.26(0.85-1.85)
Secondary and higher	0.35(0.24-0.51)	1.15(0.64-2.05)

Season		
Dry	Ref	Ref
Rainy	1.11(0.80-1.54)	1.01(0.77-1.34)

† OR: Adjusted for cluster survey design, socioeconomic characteristics, seasonality, altitude, use of mosquito nets, and residence. Educational level includes only women

*** Statistically significant (p<0.05)

3.4. Interactions among altitude, wealth category, and use of treated mosquito nets

Richest people seemed to own mosquito nets than others (P value<0.001) but no significant interaction found between Altitude and Wealth category.

Table 4 Interactions among altitude, use of mosquito nets, and wealth category

	β	Std. Error	P value
Intercept	-3.51811	0.36929	**0.000*** **
Non-Use of Mosquito nets	-0.34689	0.33783	0.30503
Poorer	-0.48800	0.37691	0.19605
Poorest	0.28025	0.29849	0.34828
Richer	-0.22289	0.43480	0.60845
Richest	-0.84581	0.55487	0.12810
<1700m	0.74136	0.35528	**0.03745 ***
Kigali	-0.46639	0.39993	0.24414
East	1.08302	0.29105	**0.0002*** **
North	-1.01865	0.40765	**0.01280 ***
South	1.00023	0.27583	**0.0003 *** **
Urban	-0.16546	0.30007	0.58161
15-29years	-0.62619	0.22313	**0.00522****
30-39Years	-1.10794	0.23339	**0.000*** **
40-49Years	-1.10794	0.23339	**0.000*** **
Girl	-0.07645	0.12253	0.532972
Primary Education	0.20605	0.19868	0.300230
Secondary & Higher	0.12659	0.29716	0.670313
Interaction			
Poorest: Non-Use of Mosquito nets	0.15359	0.29620	0.604329
Poorer: Non-Use of Mosquito nets	0.69818	0.27138	**0.010403***
Richer: Non-Use of Mosquito nets	-0.03861	0.41787	0.926416
Richest: Non-Use of Mosquito nets	-0.12049	0.51428	0.814861
Poorest: <1700m	0.14614	0.32877	0.656879
Poorer: <1700m	0.45685	0.41225	0.268359

Richer: <1700m	-0.21297	0.46472	0.646976
Richest: <1700m	-0.21115	0.58983	0.720519
<1700m: Non-Use of Mosquito nets	0.44685	0.27337	0.102818

***** P-Value<0.001; * P-Value<0.05**

4. DISCUSSION

There has been a lot of interest about factors driving the persistence of malaria in Rwanda despite various control measures that have been put in place. We assessed determinants of the persistence of malaria in Rwanda. This study revealed that altitude, non-use of ITNs, and wealth category are associated with malaria, as reported in previous studies in Africa (Bodker et al., 2003; A. M. Noor et al., 2008; Tusting et al., 2013). Non-use of ITNs (AOR = 1.34, 95% CI = 1.08–1.67), low altitude (AOR = 2.88, 95% CI = 1.90–4.36), and the poorest wealth category (AOR = 1.51, 95% CI = 1.15–1.98) were associated with the incidence of malaria. Consideration of these factors will facilitate eradication of malaria in Rwanda (WHO, 2018).

Altitude and malaria

Environmental parameters play an important role in malaria transmission because they impact the life cycle of the insect vectors and development of the parasite. The probability of malaria transmission decreases with increasing altitude (Gill, 1923); for example, in Tanzania (Bodker et al., 2003; Omondi et al., 2017). In This study, the regions affected by malaria were those at <1700 m (Figure 1), particularly the southern and Eastern Provinces(Table 2) Temperature decreases with increasing altitude and a high temperature favours breeding and survival of the insect vectors of malaria. The risk of malaria increased with decreasing altitude; people living at <1700 m asl were at greater risk of developing malaria (AOR = 2.88, 95% CI = 1.90–4.36) (Table 3).

Income level and malaria

Malaria is considered a disease of the poor; indeed, poverty is linked to the incidence of malaria (Teklehaimanot & Mejia, 2008). The incidence of malaria in Uganda reportedly increases with decreasing wealth category (Matthys et al., 2006; Tusting et al., 2016), and we found that poverty was associated with the prevalence of malaria in Rwanda (AOR = 1.51, 95% CI = 1.15–1.98).This may be because the housing of the poverty-stricken is of a standard that facilitates mosquito proliferation. Additionally, the costs of consultation, transportation, and drugs at distant health facilities may be prohibitive for poor families. Poverty can lead to employment in mining or agriculture in the jungle and/or forest, where there is an abundance of malaria vectors. Poverty also stimulates unplanned and rapid migration to undeveloped and densely populated peri-urban areas with poorly constructed housing, which facilitate breeding of mosquitos (Matthys et al., 2006; Robert et al., 2003). Thus, low-quality housing and a lack of knowledge of malaria enable disease transmission among the poverty stricken. Malaria can also be seen as a source of poverty in developing countries, as the majority of the population of such countries depends on agriculture and the rate of transmission of malaria coincides with the planting and harvesting seasons. This can result in economic and nutritional consequences for individual households and the wider community (Girardin et al., 2004).

Mosquito nets use and malaria

Sleeping beneath an insecticide treated net (ITN) is considered as an effective malaria preventive measures because in malaria endemic regions, female anopheles that transmit malaria only bite at night. ITNs act as physical barrier between an individual sleeping beneath the net and mosquito and chemicals in ITNs kill or repel mosquitoes landing on net.

Owning an ITN is not the only limiting factor to achieving malaria morbidity and mortality reduction which is associated with the use of ITNs but individuals who have ITNs must use them in order to potentially realize health impact (Pulford, Hetzel, Bryant, Siba, & Mueller, 2011). The use of ITNs is an effective malaria-control strategy, but these are beyond the financial reach of poorer families (Guyatt, Ochola, & Snow, 2002; Abdisalan M. Noor, Amin, Akhwale, & Snow, 2007). Of the population of Rwanda, 84.30% own mosquito nets, but only 66.25% use them (Table 1). The frequency of use of ITNs increased with increasing wealth category and education level and the interaction between Wealth category and ITN use was found where poorer individuals were likely to use ITNs less and suffer from malaria the most. In general, affluent people are more highly educated than poor people and tend to be more concerned with protecting their health. Non-use of ITNs was associated with an increased incidence of malaria, in agreement with a prior report that use of ITNs can prevent the transmission of malaria (A. M. Noor et al., 2008). A study done in Democratic Republic of Congo in Kinshasa reported that women who graduated secondary school or higher were more likely to own and Use mosquito nets with 3.4 times and 2.8 times respectively compared to less educated woman(Ndjinga & Minakawa, 2010).Mother's knowledge about malaria and level of education were associated with the use if ITNs in Nigeria and Kenya(A. M. Noor et al., 2008; Ordinioha, 2007).The level of education of mothers also affect their under 5 years children because children sleep with their parents thus their perception of ITNs impact children's ITN use(Eisele, Keating, Littrell, Larsen, & Macintyre, 2009; A. M. Noor, Kirui, Brooker, & Snow, 2009).

Residing in Kigali and the Northern Province was negatively associated with the risk of contracting malaria (AOR = 0.64, 95%CI = (0.29–1.40) and AOR = 0.38, 95%CI = (0.17-

0–84), respectively); however, the risk of malaria was high in the Southern and Eastern Provinces (AOR = 2.93, 95% CI = (1.73-4.94) and AOR = 3.13, 95% CI = (1.78–5.48), respectively). This was due to the fact that the eastern and southern parts of Rwanda have the lowest elevation in Rwanda. The Northern Province is the coldest part of the country, which can affect the proliferation of the mosquitoes that spread malaria. Additionally, Kigali is the capital of Rwanda and has more health-related infrastructure than any other place; moreover, its inhabitants are literate, and their income levels are higher than elsewhere, which contribute to decreased vulnerability. Household income is a determinant of where to reside. In developing countries, poor households are typically found in rural areas with no electricity and few health facilities, close to wetlands and forests as they depend on agriculture. Such areas tend to favour mosquito proliferation, leading to a risk of malaria transmission. Table 4 shows the relationship of wealth category with ITN use. The frequency of ITN use increased with increasing wealth category ($P < 0.001$). There was no interaction between ITN use or wealth category and altitude.

Education plays a key role in sustainable response to malaria, and the probability of dying from malaria decreases with increasing education level (Tusting et al., 2013). This study confirmed the role of education in malaria reduction, as the risk of malaria decreased as the level of education increased. However, in this study, type of residence and season were not associated with the incidence of malaria. This is because trained community health workers are available in rural areas, which tend to have a high proportion of uneducated people, and provide antimalarials to symptomatic individuals, particularly children <5 years of age. There were no significant difference between rainy and dry season which may due to the fact that the mean temperatures were similar in both the rainy and the dry seasons (19.67

and 19.63°C, respectively), whereas the precipitation was higher during the rainy season (132.40 versus 94.77 mm) (WorldBank, 2016).

5. LIMITATIONS AND STRENGTHS

The 2014–2015 Rwanda Demographic Health Survey was of a cross-sectional design, and so causation cannot be inferred; this precludes drawing firm conclusions as to the directions of any associations. In addition, malaria testing was only performed in women and children <5 years of age rather than in the entire population; this precludes generalisation of the associations to the entire population. The survey was performed during 7 months excluding strong dry months; therefore, we have no information on malaria in Rwanda during marked dry season (June–August). Despite these limitations, our findings provide insight into the prevalence of malaria and the related factors in Rwanda. The effects of non-use of mosquito nets, climate, and poverty on the incidence of malaria has been revealed. Our findings can be used as a reference for future studies and to support the implementation of policies and programs that aim to eradicate malaria in Rwanda.

6. CONCLUSIONS

Few studies have assessed the associations of malaria with altitude, season, and non-use of mosquito nets among the general population of Rwanda. Our findings confirm that altitude, poverty, and non-use of ITNs are associated with malaria incidence. This reaffirms the importance of taking these factors into account when formulating malaria eradication policies and measures. Longitudinal studies are needed to evaluate the associations of season, and type of residence with the incidence of malaria, which were non-significant in this study. Future interventions to reduce financial barriers to preventive measures will reduce the incidence of malaria. Effective use of ITNs is needed, and areas at low altitudes should be considered when formulating strategies to control and/or eradicate malaria. Finally, the Eastern and Southern Provinces should emphasise malaria-eradication programs, as they are more vulnerable than the other provinces.

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APPENDIX

Use of mosquito nets in general population

Parameter	**N**	**Household Members**			
		Own ITN (%)	**Use ITN (%)**	**SE**	**95% CI**
Total	54,905	83.18	60.5		
Province					
Kigali	6,366	91.21	73.63	0.019	69.72–77.53
Southern	14,293	86.85	65.09	0.014	62.34–67.84
Western	12,976	71.42	49.27	0.021	45.08–53.46
Northern	8,839	81.68	54.25	0.025	49.26–59.25
Eastern	12,431	87.74	63.94	0.014	61.11–66.78
Residence					
Urban	12,254	86.11	68.15	0.022	63.70–72.59
Rural	42,651	81.02	58.78	0.009	56.84–60.73
Education Level					
No education	16,436	72.38	61.93	0.010	59.91–63.96
Primary	30,830	81.85	58.56	0.009	56.72–60.40
Secondary	6,381	90.13	62.88	0.012	60.52–65.25
Higher	1,178	100	75.71	0.019	71.87–79.56
Wealth Category					
Poorest	10,824	67.67	46.44	0.014	43.66–49.22
Poorer	10,582	78.95	54.75	0.013	52.12–57.38
Middle	10,476	86.24	61.41	0.012	58.98–63.84
Richer	10,605	90.87	66.73	0.011	64.49–68.96
Richest	12,418	92.06	72.31	0.014	69.56–75.06

ABSTRACT IN KOREAN

국문초록

르완다에서 말라리아의 유병률에 결정 요인: 2014-2015 르완다 인구통계 및 건강 조사 자료 바탕으로 횡단면 조사

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연구배경: 말라리아는 개발 도상국 인구의 건강에 상당한 영향을 미친다. 실제로 르완다 전체 인구가이 병에 걸릴 위험이 있다. 르완다에서는 말라리아를 통제하기 위한 다양한 개입 조치가 시행되었지만 2012 년 이래로 말라리아 발생률이 증가했다. 르완다에서 끈질 기게 몰아 치는 요인을 이해하는 데 관심이 있다. 이 연구는 르완다의 말라리아 지속에 사회 경제적 및 환경적 요인, 계절성 및 살충제로 처리 모기장 (ITNs) 사용의 효과를 평가하는 것을 목표로 한다.

연구방법: 2014-2015 르완다 인구통계 및 건강 조사에서 나온 자료 (5 세 미만의 어린이와 15 ~ 49 세 사이의 여성 로 구성된 10891 가구 회원)를 분석했습니다. 이변 량 분석은 결과와 각 공 변량(소득, 고도, 교육 수준, 거주지 및 ITN 사용) 생성 백분율 사이에서 수행되었다. 각 공 변량에 대한 말라리아 음성 및 양성을 비교하기 위한 카이 제곱 검정이 수행되었다. 통계적으로 유의한 변수는 $p < 0.05$에서 말라리아와 통계적으로 유의한 변수를 평가하기 위해 다중 회귀 분석에서 분석을 하였다. 분석은 샘플 무게, 계층화 및 클러스터링에 대한 조사 명령 조정을 사용하여 R x64 3.8.에서 수행되었다. QGIS3.8은 말라리아의 지리적 분포를 나타내는 데 사용되었다.

연구결과: 최저 소득 수준은 말라리아 발병률과 관련이 있었다 (AOR = 1.55, 95 % CI = (1.18-2.05)). 해수면 고도 1700 m 이상에서 ITN의 사용이 현저히 떨어진 곳 말라리아 발병률과 관련이 있다 (조정 된 교차 비 (AOR) = 2.90, 95 % 신뢰 구간 [95 % CI] = 1.92-4.38, AOR = 1.30, 95 % CI = 1.04-1.61). 해수면 1700 미터 미만의 거주지를 갖는 경우 및 ITN의 비사용은 말라리아의 발병과 유의 한 관련이 있었다 (AOR = 2.90, 95 % CI = 1.92-4.38, AOR = 1.30, 95 % CI = 1.04-1.61). 계절과 거주유형은 말라리아 유병률과 유의 한 관련이 없었지만 여성은 말라리아에 걸릴 위험이 어린이보다 낮았다.

연구결론: 소득 수준, 해수면 1700 미터 미만의 거주한 경우 및 모기장 비사용은 말라리

아의 유병과 통계적으로 유의한 연관성이 있었다. 따라서 말라리아 방제 전략을 수립 할 때 저소득층과 저지대에서 잠재적인 개입을 고려해야 하며 말라리아의 확산을 통제하기 위해 ITN을 사용하는 것이 강조되어야 한다.

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주요어: 말라리아, 모기장, 계절, 고도, 거주 형태, 소득 수준

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