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Full Length Research Paper

Socio-economic, demographic and geographic indicators on the malaria rapid diagnosis test (RDT)

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This study evaluates the effects of socio-economic, demographic and geographic indicators on the malaria rapid diagnosis test (RDT), using the baseline malaria indicator survey of 2007. This survey covered the Amhara, Oromiya and Southern Nations, Nationalities, and People's Region (SNNPR) of Ethiopia. A total of 224 clusters of, on average, 25 households each were selected. In total, 28,994 individuals participated in the survey. A generalized linear mixed model was used to analyze the data where the response variable was the presence or absence of malaria using the RDT. The results showed that for households with toilet facilities, clean drinking water and more living space, the chances of testing positive for malaria RDT decreased. Moreover, using malaria nets and spraying the house walls with anti-mosquito were found to be effective control measures.

Key words: Cluster sampling, interaction effect, mixed model, odds ratio, rapid diagnostic test.

INTRODUCTION

While malaria has long been a cause of human suffering and mortality in Sub-Saharan Africa (Eisele et al., 2010), in Ethiopia the problem is particularly severe. Here, it is the major cause of illness and death (Schabenberger and Gotway, 2005), with 75% of the total area being malarious (Cressie, 1991), and approximately 68% of the Ethiopian population living in these affected areas. Annually, about 4 to 5 million Ethiopians are affected by malaria (Federal Ministry of Health (FMH), 2004a; World Health Organization (WHO), 2006a). Malaria transmission in Ethiopia is seasonal, depending mostly on altitude and rainfall, with a lag time varying from a few weeks before the beginning of the rainy season to more than a month after the end of the rainy season (Deressa et al., 2003; Tulu, 1993).

Malaria epidemics in Ethiopia are relatively frequent (WHO, 2006b; Zhou et al., 2004), involving highland or highland fringe areas, mainly 1,000 to 2,000 meters above sea level (Adhanom, 2006; FMH, 2006; Tulu, 1993). Malaria transmission peaks bi-annually from September to December and April to May, coinciding with the major harvesting seasons (FMH, 2004a). This seasonality has serious consequences for the subsis-tence economy of Ethiopia's countryside and for the nation in general. Early diagnosis and prompt treatment is one of the key strategies in controlling malaria. For areas where laboratory facilities are not available, clinical diagnosis is widely used (FMH, 2004b; WHO, 1999). To diagnose malaria, microscopy remains the standard method. However, it is not accessible and affordable in most peripheral health facilities. The recent introduction of rapid diagnosis test (RDT) for malaria has become a significant step forward in case detection, management and reduction of unnecessary treatment in Ethiopia (Tekola et al., 2008).

In order to estimate the prevalence of malaria parasites in Ethiopia, a population based survey was conducted in 2006/2007. Rapid diagnostic tests as well as the conventionally accepted diagnostic tests using standard microscopy of peripheral blood slides were used for this survey. Both tests use *finger-stick* or *venous* blood. The level of disagreement in this survey between the results of microscopy and RDT was studied by Tekola et al. (2008) and found to be insignificant.

The objective of this study is to identify the socio-economic, demographic and geographic risk factors associated with the prevalence of malaria obtained from the rapid diagnosis tests.

METHODS AND MATERIALS

Study design

The Carter Center (TCC) conducted a baseline household cluster malaria survey in Ethiopia in 2007. The questionnaire was developed as a modification of the malaria indicator survey (MIS) household questionnaire. The questionnaire had two parts; the household interview and malaria parasite form.

For the baseline household cluster malaria survey which was conducted by TCC, a multi-stage cluster random sampling was used. By assuming the lowest measurement of prevalence malaria indicator, the sample size was estimated. Therefore, for TCC baseline household cluster malaria survey in Amhara, Oromiya and the Southern Nations, Nationalities and People's (SNNP) regions of Ethiopia which was conducted in 2007, the design was a population-based household cluster survey. Based on these clusters, zone-level estimates of indicators were obtained for Amhara region, and sub-regional estimates were obtained for Oromiya and SNNPR. Furthermore, the sampling design was involved to select households within each first-stage cluster, or Kebele (smallest administrative unit in Ethiopia). From the 224 selected Kebeles, 25 households were chosen, from which even-numbered households were selected for the malaria (RDT). All individuals in these 12 households (even-numbered households) were eligible for individual interviews. Furthermore, each room in the house was listed separately. By using the mosquito nets as a guide, it was possible to determine the number of persons sleeping in each room. This information was useful in determining the number of sleeping rooms both within and outside the house. In addition to the number of rooms and number of nets, the persons sleeping under each net were listed. Further studies on the sampling procedure for the survey were studied by different researchers (Emerson et al., 2008; Shargie et al., 2008).

Malaria parasite testing was performed on consenting residents. The blood sample for malaria RDT was collected by taking finger-prick blood samples from participants. The RDT used was ParaScreen which is capable of detecting both *Plasmodium falciparum* and other *Plasmodium* species. Participants with positive rapid tests were immediately offered treatment according to national guidelines.

Variable of interest

Response variables

The outcome of interest is the RDT result. RDTs assist in the diagnosis of malaria by detecting evidence of malaria parasites in human blood and are an alternative to diagnosis based on clinical grounds or microscopy, particularly where good quality microscopy services cannot be readily provided. Thus, the response variable was binary, indicating that either a person was positive or not positive.

Independent variables

The independent predictor variables consisted of baseline socio-economic, demographic and geographic variables, which were collected from each household. The socio-economic variables were the following: main source of drinking water; time taken to collect water; toilet facilities, availability of electricity, access to radio and television, total number of rooms, main construction material of the rooms' walls, main construction material of the room's roof and main construction material of the room's floor, incidence in the past 12 months of anti-mosquito spraying, use of mosquito nets and total number of nets. Geographic variables were region and altitude, and demographic variables were gender, age and family size. Of these variables, age and sex were collected at the individual level, while altitude, main source of drinking water, time taken to collect water, toilet facilities, availability of electricity, radio, television, total number of rooms, main construction material of walls, roof and floor, incidence of anti-mosquito spraying and use of mosquito nets were all collected at the household level.

The statistical model

A generalized linear mixed model (GLMM) was used to analyze the data. Classical linear models can be generalized using the generalized linear models (GLMs) to the exponential family of sampling distributions. These models have an immense impact on both theoretical and practical aspects in statistics. The term 'mixed' in the GLMMs means that the random effects and the fixed effects are mixed together to get a modified model. This can overcome the over-dispersion in the data and at the same time, accommodate the population heterogeneity. Therefore, the addition of random effects allows accommodating correlation in the context of a broad class of models for non-normally distributed data. These models become more applicable in practical situations. The logistic regression model, which includes the mixed effects, is a common choice for analysis of multilevel dichotomous data. In the GLMM, this model utilises the logit link, namely:

$$g(\mu_{ijk}) = logit\,(\mu_{ijk}) = log\left[\frac{\mu_{ijk}}{1-\mu_{ijk}}\right] = \eta_{ijk},$$

The conditional expectation $\mu_{ijk} = E(Y_{ijk} | v_i, x_{ijk}, z_{ijk})$ equals $p(Y_{ij} = 1 | v_i, x_{ij})$, i.e., the conditional probability of a response given the random effects. Here, Y_{ijk} corresponds to the i^{th} respondent in the j^{th} household within k^{th} probabilistic sampling unit (PSU). Therefore, this model can also be written as:

$$P\left(Y_{ijk} = 1 | v_i, x_{ijk}, z_{ijk}\right) = g^{-1}\left(\eta_{ijk}\right)$$

Where, the inverse link function $g^{-1}\left(\eta_{ij}\right)$ is the logistic cumulative distribution function (cdf), namely:

$$g^{-1}\left(\eta_{ijk}\right) = [1 + exp(-\eta_{ijk})]^{-1}.$$

Table 1. Type 3 analysis of effects for the GLMM.

Effect	Num DF	F value	P > F
Age	1	10.16	0.0014
Gender	1	0.12	0.7257
Family size	1	75.32	<0.0001
Region	2	0.02	0.9761
Altitude	1	215.47	<0.0001
Main source of drinking water	2	6.59	0.0014
Time to collect water	3	7.46	<0.0001
Toilet facilities	2	5.2	0.0055
Availability of electricity	1	17.61	<0.0001
Availability radio	1	2.82	0.0732
Availability television	1	4.5	0.034
Number of rooms/person	1	38.49	<0.0001
Main material of the room's wall	2	12.94	<0.0001
Main material of the room's roof	2	2.07	0.1262
Main material of the room's floor	2	13.37	<0.0001
Spraying of anti- mosquito	1	986.9	<0.0001
Number of months room sprayed	1	944.72	<0.0001
Use of mosquito nets	1	11.62	0.0027
Number of nets/person	1	13.48	0.0002
Age and gender	1	0.027	0.9784
Main source of drinking water and main material of the room's roof	4	4.57	0.0004
Gender and use of mosquito nets	1	11.59	<0.0001
Time to collect water and main material of the room's floor	4	14.57	0.0024
Gender & main source of drinking water	1	33.46	<0.0001
Gender and main material of the room's floor	2	5.67	0.0035
Gender and spraying anti-mosquito spray	1	849.57	<0.0001
Use of mosquito nets and number of nets per person	1	849.57	<0.0001
Age, gender and source of drinking water	4	8.42	<0.0001
Age, gender and availability of electricity	2	7.8	0.0004

Num DF = Number difference.

The logistic distribution simplifies parameter estimation because the probability density function (pdf) is related to the cdf (Agresti, 2002).

The survey logistics model is an alternative statistical methodology (Natarajan et al., 2008) used to identify factors affecting the malaria risk. Studies conducted by Ayele et al. (2012), using survey logistic method, concluded that malaria epidemic in Amahara, Oromia and SNNP regions of Ethiopia is associated with the socio-economic, demographic and geographic factors (Ayele et al., 2012). But this model is survey based, whereas the Kebeles are chosen at random which could result in some variability between the sampling units. Such a study of the identification of the socio-economic, demographic and geographic risk factors is helpful to identify households who are in a critical need of intervention. Generalized linear mixed models (GLMM) explore the idea of statistical models that incorporate random factors into generalized linear models. GLMMs add random effects or correlations among observations to a model, where observations arise from a distribution in the exponential family. The generalized linear mixed model has many advantages. The use of GLMMs can allow random effects to be properly specified and computed, and errors can also be correlated. In addition to this, GLMMs can allow the error terms to exhibit non constant variability while also allowing investigation into more than one source of variation. This ultimately leads to greater flexibility in modelling the dependent variable.

RESULTS

Model selection was achieved by first including into the model all predictor variables and then evaluating whether or not any interaction terms needed to be incorporated. This was determined by fitting to the model, one at a time, each of the interaction terms formed from the predictor variables, and retaining in the model only those interaction terms which were significant. This process continued until the final maximal model was obtained. The final chosen model for the malaria rapid diagnosis test contained all main effects as well as six two-way interaction terms, and two three-way interaction terms. The final model is presented in Table 1.

Age, family size, altitude, main source of drinking water, time taken to collect water, availability of toilet facilities, availability of television, number of rooms per person, main construction material of the rooms' walls, roof and floors, incidence in the past 12 months of anti-mosquito spraying, number of months the room sprayed and total number of nets per person were found to be significant main effects. From these main effects, the following were involved in the interaction effects: main source of drinking water; time to collect water; availability of electricity; main construction material of the rooms' walls, roof and floor; incidence of anti-mosquito spraying; and the use of mosquito nets. There are two three-way and eight two-way significant interaction terms. The three-way interaction term is between age, gender and main source of drinking water and between age, gender and availability of electricity. The two-way interaction terms are between source of water and roof material; between number of nets per person and use of mosquito nets; between gender and availability of electricity; between gender and floor material; between time to collect water and construction material of room's floor; between gender and application of anti-mosquito spray; and between gender and number of months the room was sprayed. The interpretation of the results is presented as follows.

Tables 2 and Table 3 presents odds ratio estimates associated with age, gender, family size, region, altitude, toilet facilities, main source of drinking water, time to collect water, availability of electricity, radio and television, number of rooms per person, main construction material of room's roof, wall and floor, application of anti-mosquito spray, number of months the room sprayed, use of mosquito nets and number of nets per person. Our result reveals that malaria risk is high for young household members (OR = 0.992, P-value < 0.0002). Based on the results, for a unit increase in family size, the odds of positive RDT for individuals increases by 3.76% (OR = 1.0376, P-value < 0.0001). Furthermore, for a unit increase in altitude, the odds of positive RDT decreases by 2.2% (OR = 0.978, P - value <0.0001). With reference to individuals with no toilet facility, malaria RDT was seen to be positive for more individuals with toilet with flush (OR = 0.894, P-value = 0.0141) followed by pit latrines (OR = 0.878, P-value = 0.005). Moreover, for a unit increase in the number of total rooms, the odds of malaria diagnosis test for individuals decreased by 5.5% (OR = 0.945, P-value = 0.004).

Interaction effects

Figures 1 and 2 shows the distribution of malaria RDT against the main source of drinking water for both males and females, respectively. As age increased, positive malaria diagnosis was less likely for males than for females who were using protected, unprotected and tap water for drinking. Furthermore, as age of respondents increased, malaria RDT was less likely to be positive for individuals who used tap water for drinking (OR = 0.98, P - Value < 0.0001) for males and (OR = 1.077, P - Value < 0.0001) for females. More specifically, positive malaria diagnosis rates increased with age for females whereas it decreased for males as age increased (Figures 1 and 2). The figures further show that the gap in the RDT between respondents using unprotected, protected and tap water for drinking widens with increasing age.

The relationship between age, gender and availability of electricity is presented in Figure 3. As the figure indicates, positive malaria RDT decreases as age increases for both male and female respondents, whether or not they had access to electricity. However, the rate of decrease was not the same for males and females after controlling for other covariates in the model. The rate of increase for females who responded positively to having electricity was 9.14% higher than the other categories (OR = 1.0914, p-value < 0.001). Probabilities for this interaction are presented in Figure 3.

Interaction effects between main source of water and main construction material of the room's roof is presented in Figure 4. From the figure, it is clearly seen that with respondents who reported using tap water as well as protected and unprotected water for drinking, positive rapid diagnosis of malaria was significantly higher when the roof of the house was thatched, followed by those who occupied a stick and mud roof and finally respondents living in a house with a corrugated iron roof. The difference in RDT between the respondents' use of tap, protected and unprotected sources of drinking water and having a thatch or stick/mud roof was particularly significant. It has also shown that for a corrugated iron roof, positive RDT was significantly lower for respondents who reported using tap water for drinking than for those who were using protected and unprotected water. The other two-way interaction effect which is significant is between the time taken to collect water and main construction material of the room's floor (Table 1). This result is presented graphically in Figure 5. Positive RDT was significantly higher in a room with an earth or dung and plaster floor than in one with cement or wooden floors for respondents who took < 30 min and > 90 min to collect water. But for respondents who took less than 90 min to collect water and had a cement floor, positive rapid diagnosis is low. Furthermore, with respondents who took between 30 to 40 min to collect water, there was lower positive RDT for respondents with an earth or dung and plaster floor and a wooden floor.

The relationship between the main construction material of the room's floor and gender for a household is presented in Figure 6. As the figure indicates, positive RDT was significantly higher for males than females with respondents who reported having an earth or dung and plaster floor (OR = 4.911, P-value = 0.001) as well as for

Table 2. Estimates of odds ratio for main effects.

Effect	Estimate	OR	95% CI		P-value
			Lower	Upper	
Intercept	0.622	1.863	1.369	2.536	<0.0001
Age	-0.009	0.992	0.987	0.996	0.0002
Gender (Ref. Male)					
Female	-0.027	0.973	0.637	1.487	0.8995
Family size	0.037	1.038	1.018	8.118	<0.0001
Region (Ref. SNNP)					
Amhara	0.004	1.044	0.972	1.036	0.8271
Oromiya	0.002	1.072	0.963	1.043	0.9053
Altitude	-0.007	0.978	0.945	0.998	<0.0001
Main source of drinking water (Ref. protected water)					
Tap water	1.591	4.909	1.892	7.751	<.0001
Unprotected water	0.725	2.065	1.066	3.902	0.031
Time to collect water (Ref. less than 30 min)					
30 - 40 min	0.721	2.056	1.066	3.900	0.031
40 - 90 min	1.470	4.349	2.284	8.373	<0.0001
> 90 min	0.069	1.071	0.959	1.065	0.6932
Availability of toilet facility (Ref. No facility)					
Pit latrine	-0.130	0.878	0.694	0.940	0.005
Toilet with flush	-0.112	0.894	0.610	0.956	0.0141
Availability of electricity (ref. no)					
Yes	0.166	1.181	0.987	1.133	0.1098
Availability of radio (ref. yes)					
No	-0.022	0.978	0.980	1.009	0.4328
Availability of television (ref. yes)					
No	-0.104	0.901	0.845	0.960	0.0013
Number of rooms/person	-0.057	0.945	0.908	0.982	0.004
Main material of room's wall (Ref. cement block)					
Corrugated metal	-0.329	0.719	0.700	0.740	<0.0001
Mud block/stick/wood	-0.322	0.725	0.570	0.922	0.0086
Main material of room's roof (Ref. Corrugate)					
Thatch	0.006	1.006	0.995	1.018	0.0269
Stick and mud	0.045	1.046	1.016	1.077	0.0024
Main material of room's floor (Ref. /Local dung plaster)					
Cement-floor	-0.174	0.840	0.624	1.132	0.2532
Wood-floor	-0.136	0.872	0.657	1.158	0.3456
Use of anti-mosquito spray (ref. No)					
Yes	-0.396	0.673	0.656	0.690	<0.0001
Number of months the room sprayed	-0.053	0.949	0.945	0.953	<0.0001
Use of mosquito nets (ref. No)					
Yes	-0.009	0.991	0.999	1.019	0.0778
Number of nets/person	-0.034	0.966	0.949	0.984	0.0002

Table 3. Estimates and odd ratios for interaction effects.

Effect	Estimate	OR	95% CI Lower	95% CI Upper	P-value
Main source of drinking water and main material of the room's roof (ref. Protected water and cement block)					
Tap water and mud block/stick/wood	-0.034	0.967	0.944	0.991	0.006
Tap water and corrugated metal	-0.264	0.768	0.626	0.829	0.019
Unprotected water and Mud block/stick/wood	-0.008	0.992	0.966	1.000	0.020
Unprotected water and Cement block	-0.032	0.968	0.906	1.035	0.549
Time to collect water and material of room's floor (ref. less than 30 min and earth/local dung plaster)					
Greater than 90 min and Cement	-0.039	0.962	0.857	1.079	0.5048
Greater than 90 min and Wood	-0.294	0.745	1.201	1.500	<0.0001
Between 30 - 40 min and Cement	-0.016	0.985	0.980	1.053	0.3901
Between 30 - 40 min and Wood	0.145	1.156	1.147	1.165	0.0048
Between 40 - 90 min and Cement	-0.172	0.842	1.226	1.151	<0.0002
Between 40 - 90 min and Wood	0.200	1.221	1.312	1.137	0.3901
Gender and main source of drinking water (ref. male and protected water)					
Female and tap water	0.0169	1.017	0.941	1.099	0.0488
Female and unprotected water	-0.0795	0.924	0.854	0.999	0.0467
Gender and material of room's floor (ref. male and earth/local dung plaster)					
Female and cement	-0.0175	0.983	0.619	0.998	0.0408
Female and wood	0.2741	1.315	0.859	2.014	0.0075
Gender and use of mosquito nets (ref. male and yes)					
Female and no	-0.034	0.967	0.964	0.969	<0.0001
Gender and use of anti-mosquito spray (ref. male and no)					
Female and yes	0.0018	1.002	0.985	1.030	0.0055
Number of nets per person and use of mosquito nets (ref. No)					
Yes	0.00491	1.005	1.000	1.010	0.0467
Age and gender (ref. Male)					
Age and female	0.0336	1.034	0.992	1.002	0.4011
Age, gender, main source of drinking water (ref. male and protected water)					
Female and tap water	-0.00098	0.999	0.998	1.000	0.0119
Female and unprotected water	0.00199	1.002	1.001	1.003	<0.0001
Age, gender and electricity (ref. Male and yes)					
Female and no	0.00335	1.003	0.995	1.105	0.0003

those who reported having a wooden floor in their house (OR = 2.039, P-value = 0.031). There was however, no significant difference in positive RDT between females and males who reported having a room with a cement floor. The interaction effect between gender and main source of drinking water is presented in Figure 7. The figure shows that the risk of malaria for households using unprotected water is significantly higher than for those households who reported having protected and tap water for both males and females. Moreover, for female members of the household, the risk of malaria was higher for those households who reported having unprotected

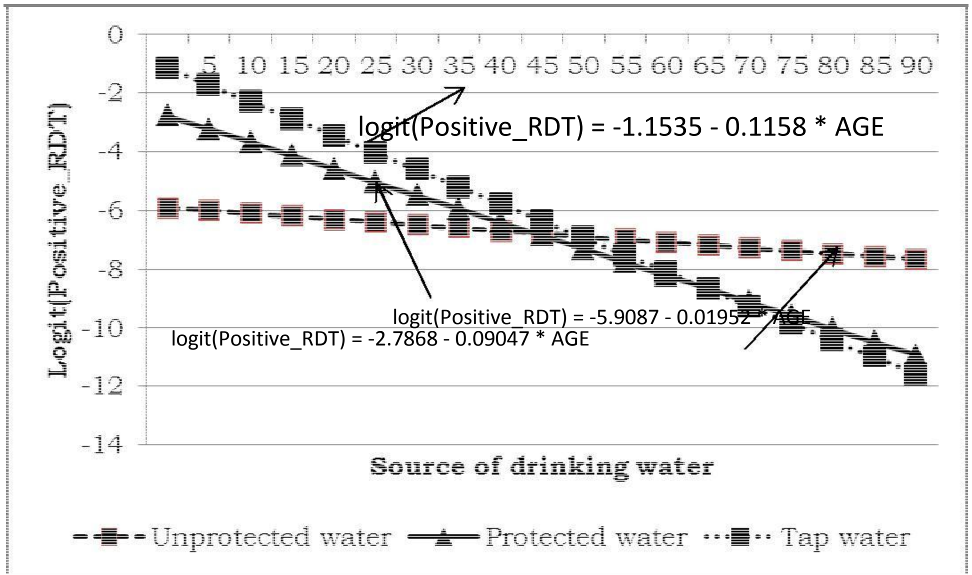

Figure 1. Log odds associated with rapid diagnosis test and age for male respondents with source of drinking water.

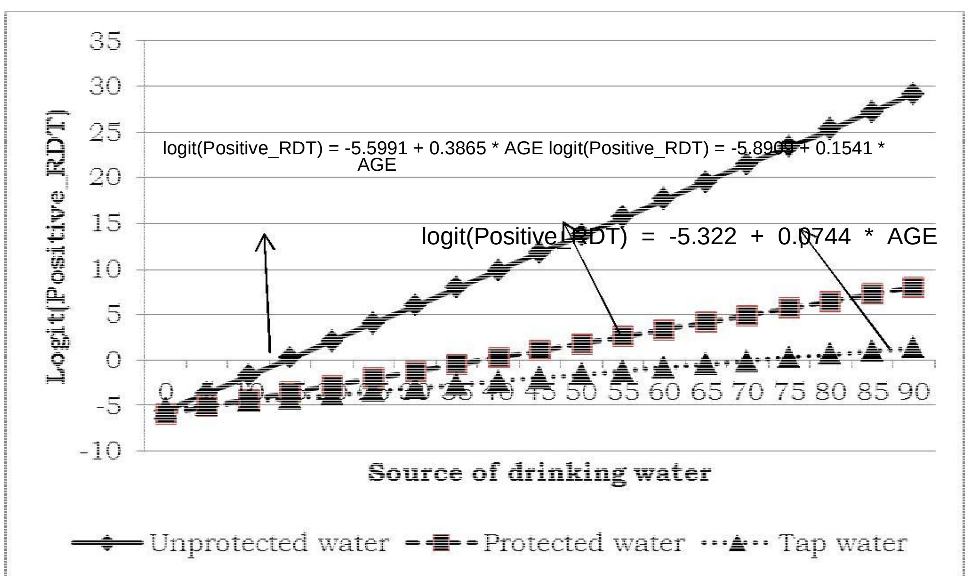

Figure 2. Log odds associated with rapid diagnosis test and age for female respondents with source of drinking water.

water.

Figure 8 presents the interaction effect between the use of anti-mosquito spray and gender for individuals. Prevalence of malaria was significantly higher for male than for female respondents who were living in a house treated with anti-mosquito spray. For males living in a house, which was not treated with anti-mosquito spray, the positive malaria result was significantly higher than it was for females. Similarly, the interaction effect between use of mosquito nets and gender is presented in Figure 9. As the figure indicates, the risk of malaria is higher for males than for females using mosquito nets when sleeping. As the number of mosquito nets increased, the risk of malaria was less likely for household members with and without nets. However, the risk of malaria was found to be much lower for individuals as the number of nets increased (Figure 10). This figure shows that for individuals with and without the use of mosquito nets, the

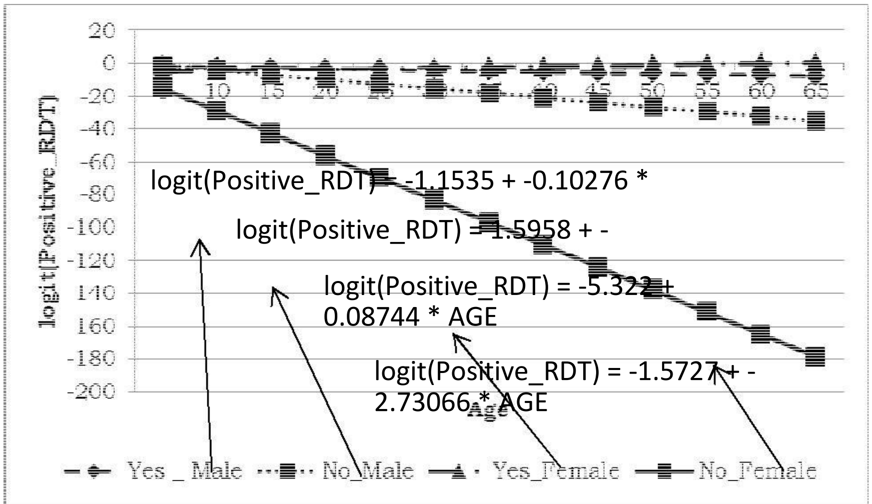

Figure 3. Log odds associated with rapid diagnosis test with age for male and female respondents with availability of electricity.

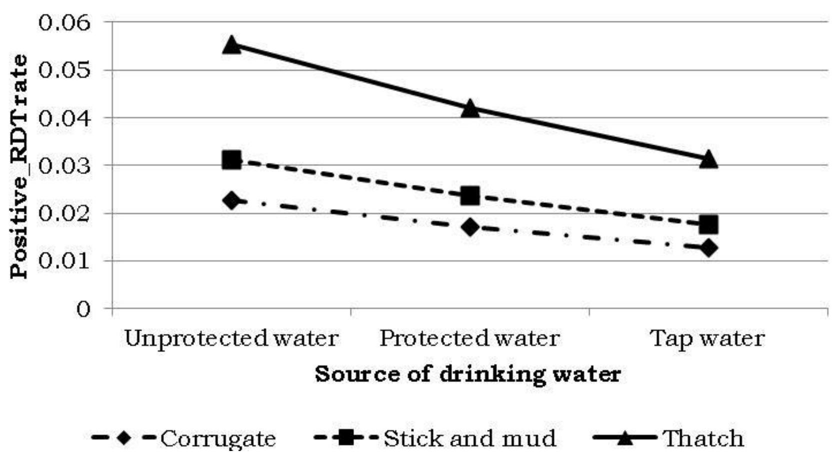

Figure 4. Log odds associated with rapid diagnosis test and source of drinking water with material of the room's roof

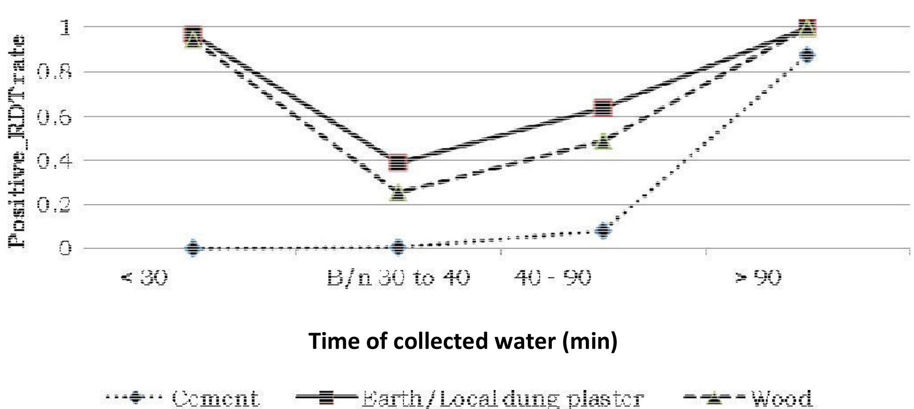

Figure 5. Log odds associated with rapid diagnosis test and time to collect water with material of the room's floor.

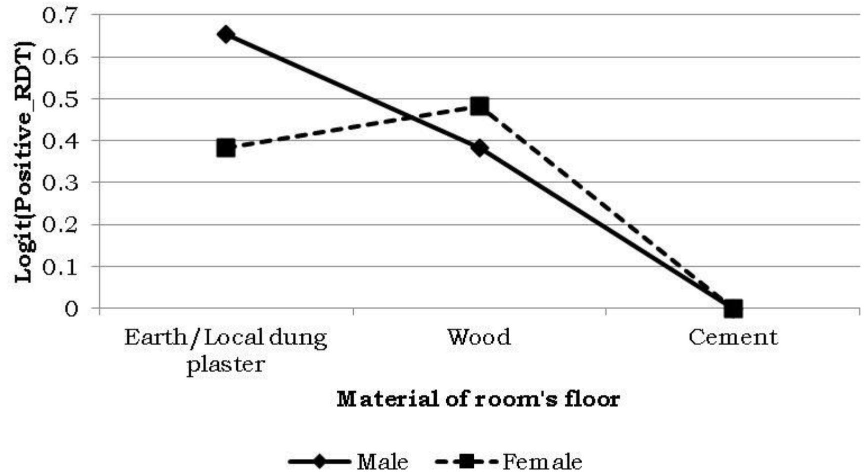

Figure 6. Log odds associated with rapid diagnosis test and material of room's floor with gender.

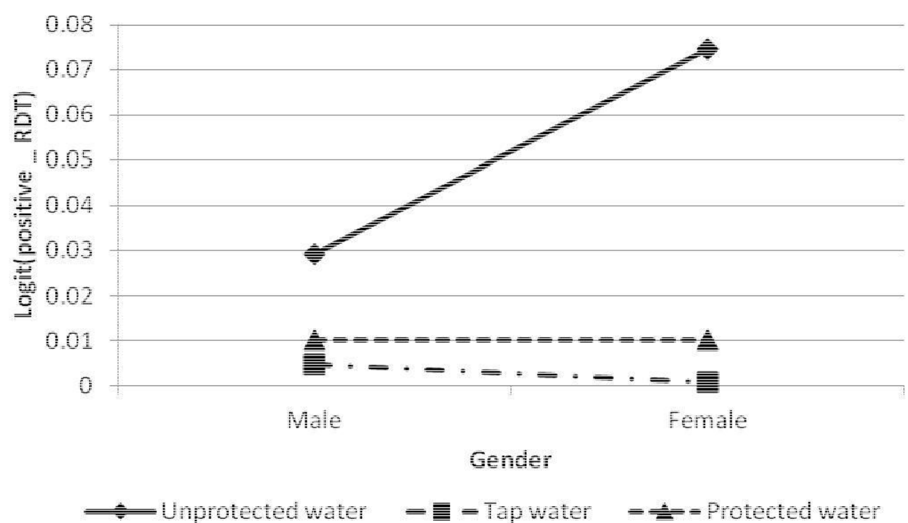

Figure 7. Log odds associated with rapid diagnosis test and main source of drinking water with gender.

risk of malaria decreased as the number of net ownerships in the household increased.

DISCUSSION

Malaria is normally referred to as a disease of poverty and related to poor socio-economic factors (Hay et al., 2004). Malaria disproportionately affects poor people who cannot afford treatment or have limited access to health care. Families and communities are then trapped in a downward spiral of poverty (Worrall et al., 2002). Since poverty is related to socio-economic factors, it is important to understand the linkages between malaria and poverty. Identifying the factors that increase the risk of malaria can be used to guide government policy-makers into creating and implementing more effective policies to tackle the disease.

SAS version 9.2 was used for the analysis of the data. Because of the nature of the methodology of the study and socio-economic, demographic and geographic variables are related. This might cause the confounding

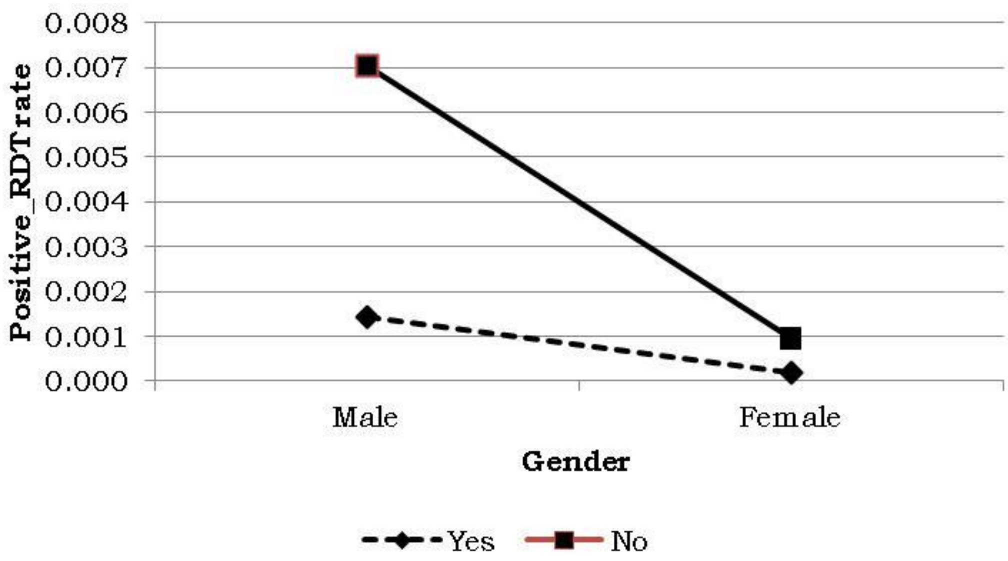

Figure 8. Log odds associated with rapid diagnosis test and anti-mosquito spraying of respondents with gender.

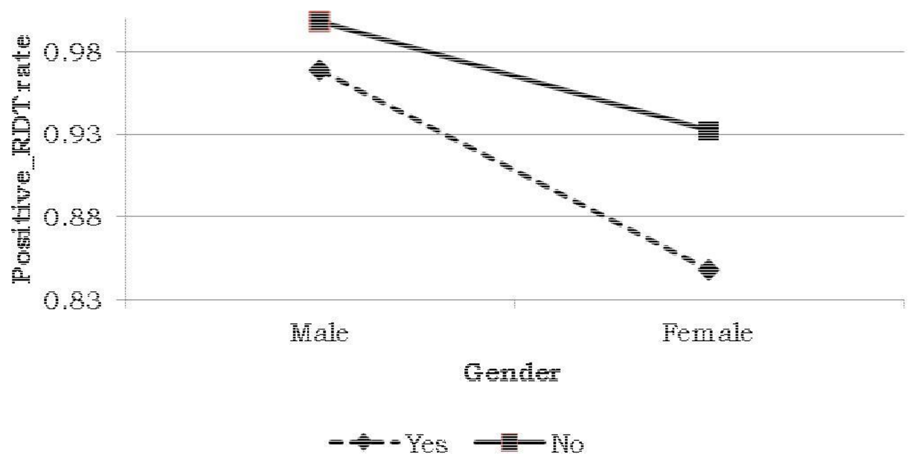

Figure 9. Log odds associated with rapid diagnosis test and use of mosquito nets with gender at individual level.

problem. Therefore, to avoid confounding effects, the model was fitted in two steps. The model was fitted to each predictor variables one at a time. In stage two, the significant predictors were retained in the model. In addition to the main effects, possible combinations of up to three-way interaction terms were added and assessed to further avoid and mitigate the problem of confounding.

Majority of studies conducted so far have suggested that malaria could be linked to poverty. The global distribution of malaria also supports this claim because malaria is concentrated to the poorest continents and countries. Therefore, our study supports the fact that malaria is related to poverty. The study indicates that socio-economic, demographic and geographic factors are responsible for the transmission of malaria. These factors are age, family size, region, altitude, main source of drinking water, time taken to collect water, toilet facilities, availability of electricity, availability of radio, total number of rooms, main construction material of the room's walls, main construction material of the room's floor, use of anti-mosquito spray, use of mosquito nets and total number of nets were the major factors associated with malaria RDT results. In addition to the main effects, three-way and two-way interaction effects were identified. The three-way interactions were between age, gender and main source of drinking water and age, gender and availability of electricity. The two-way interaction effects were between main source of drinking water and main construction

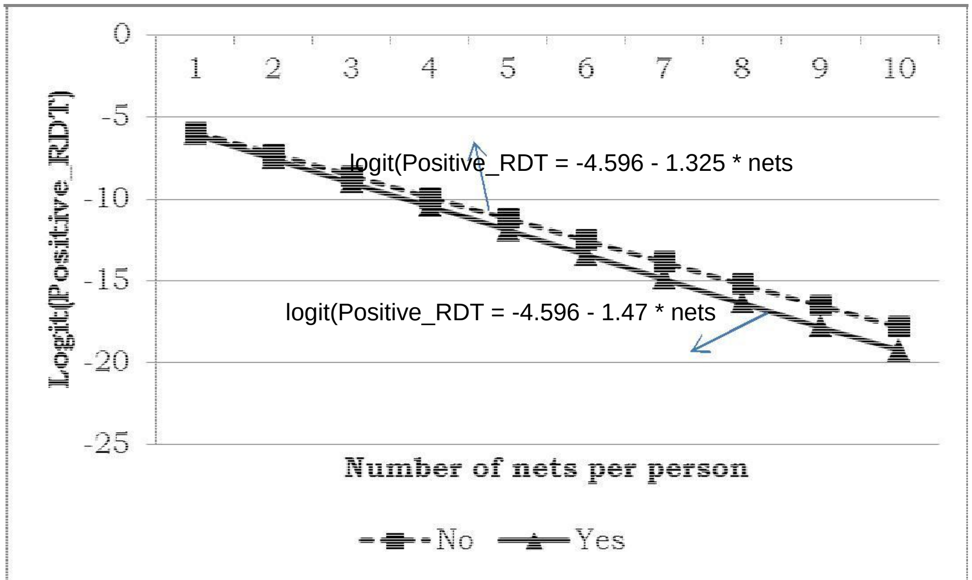

Figure 10. Log odds associated with rapid diagnosis test and use of mosquito nets with number of nets per person.

material of the room's roof, time taken to collect water and main construction material of the room's floor, age and gender, gender and main source of drinking water, gender and availability of electricity, and gender and main construction material of the room's floor.

In the present study, the effect of socio-economic factors shows that residents with no toilet facilities were found to be at more risk of malaria than those with toilet facilities. Additionally, malaria prevalence is low for households with a greater number of rooms in the house. On the other hand, having more mosquito nets over beds was found to be one way of reducing the risk of malaria. The prevalence of malaria for households with access to clean water was found to be less. Malaria rapid diagnosis was found to be higher for those respondents living in thatched houses, or ones with stick and mud roofs. Therefore, having a house with a corrugated iron roof was found to reduce the risk of malaria. Furthermore, the prevalence of malaria for households with earth and local dung and plaster floors was found to be higher. Moreover, the treatment of walls of houses with anti-mosquito spray was found to be one means of reducing the risk of malaria.

Based on demographic factors associated with malaria, our findings showed that females and children are at a greater risk. Furthermore, the malaria prevalence rate was found to be less for households with fewer people in the house. Malaria prevalence was similarly associated with geographic factors. The association between malaria and altitude showed that malaria prevalence is higher for households who are living at lower altitudes.

The result of this study supports the result from the majority of previous studies. These studies were conducted conducted to understand the distribution of malaria. Moreover, these studies have suggested that malaria could be linked to poverty. Therefore, better understanding of the relationships between malaria and poverty is important to design effective policies (Hay et al., 2004; Mendis et al., 2009). Furthermore, the findings of this study have similar results to some of the results from previous studies (Banguero, 1984; Koram et al., 1995; Sintasath et al., 2005). In 1998 and 2000, study was conducted by (Ghebreyesus et al., 2000; Snow et al., 1998) in Ethiopia and Kenya, respectively. In this study, the assessment of different types of materials used in the construction of walls, roofs and floors of a house was done. Therefore, from the study, it was possible to observe association between any roof, wall and floor material and risk of malaria. Therefore, the finding of this study supports the result from the previous studies. Similarly, the use of mosquito nets was studied by different researchers. Therefore, the findings of these studies support the outcome of this study (Messina et al., 2011).

CONCLUSION

The government of Ethiopia has adopted various strategies to control malaria. These include early diagnosis, prompt treatment, selective vector control, epidemic prevention and control. In addition to this, the government has supporting strategies such as human resource development, monitoring and evaluation. One of the government's key goals in the control of malaria is to achieve the complete elimination of malaria within those geographical areas with historically low malaria transmission and achieve near zero malaria transmission in the remaining malarious areas of the country. For this reason, evidence based strategies to prevent malaria is an attractive strategy for the country (Goovaerts, 1997). Therefore, the results from this study showed that malaria is associated with socio-economic, demographic and geographic factors, mainly influenced by poverty levels. Malaria is generally regarded as a disease of poverty. The more wealthy households who can afford to have toilet facilities, a greater number of rooms in the house, clean drinking water, and well built houses were found to be less affected by malaria. Furthermore, it was found that women and children are more vulnerable to malaria. Lack of bed nets contributes to this vulnerability. Moreover, as our results indicate having more bed nets is one means of reducing malaria and evidence suggests that households which are unable to afford sufficient mosquito nets, due to large families and low incomes, are more affected by malaria. Women and children are also exposed to mosquito bites while they are travelling long distances to fetch water. As the wealthier households were found to be less vulnerable to malaria than the poor households, improving the living conditions of the communities could be one way of achieving the malaria control goals set by the health professionals.

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