Epidemiological Factors Determining Clinical Malaria in the Highlands of Western Kenya: Case Study of Iguhu Location

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Abstract

This paper reports findings on the prevailing "epidemiological factors that determine occurrence of clinical malaria in the highlands of western Kenya, a case study of Iguhu location. In this study, the risk factors associated with clinical malaria in western Kenya highlands were evaluated. A simple household survey of existing clinical malaria cases and their age-matched cohorts was undertaken to collect information on the potential exposure factors and prevailing socio-economic status. Mosquito samples were harvested from participants' houses for identification and cataloging. The differences in parasite and vector populations in clinical malaria cases and controls were determined using the "t-test". The results showed that sex, age, household population, education level and occupation status of the household head were not significant determinants for clinical malaria in the area of study. These was in contrast, to families whose spouses were employed and educated to tertiary level that exhibited lower infections rates since they had used insecticide treated nets (ITNs) prophylaxis and mosquito prevention measures. These significantly reduced the disease incidence suggesting that socio economic factors played a role in the ailment control. These findings show that clinical malaria incidence in western Kenya highlands is likely to be influenced by both biotic and abiotic factors including parasite and vector densities suggesting that any successful eradication program should be directed towards prevailing local conditions in a given area.

Introduction

Malaria is a mosquito-borne infectious disease caused by *Plasmodium* parasites. It's widespread in tropical and subtropical regions, including parts of the Americas, Asia, and Africa (Snow *et al.,* 2005). This infection is commonly associated with poverty, and can indeed be a cause of poverty (Singh, 2004) and a major hindrance to development. Five species of the plasmodium parasite can infect humans: the most serious forms of the disease are caused by *Plasmodium falciparum.* Malaria caused by *Plasmodium vivax*, *Plasmodium ovale* and *Plasmodium malariae* is a milder disease in humans that is not generally fatal. A fifth species, *Plasmodium knowlesi*, is a zoonosis that causes malaria in macaques but can also infect humans (Singh, 2004). Symptoms of malaria include fever, headache, and vomiting, and usually appear between 10 and 15 days after the mosquito bite (Snow *et al.,* 2005).

Malaria is transmitted from one person to another by the female anopheline mosquitoes. There are about 380 species of anopheline mosquito, but only 60 or so are able to transmit the parasite. The anophelines breed in water, each species having its preferred breeding grounds, feeding patterns and resting place (Anonymous, 2010). Both *Anopheles gambiae* and *Anopheles funestus* are the most common species present in the Highlands of Western Kenya and play a major role in malaria transmission this region (Goufa *et al.,* 2007). However, the anthropophilic *Anopheles gambiae* is the most effective vector and is one of the reasons why malaria is so prevalent in Africa (Anonymous, 2010).

Malaria distribution within a geographical area is heterogeneous and can vary greatly between villages and households (Greenwood *et al.,* 1989; Gamage-Mendis *et al.,* 1991). Well known risk factors for malaria include distance to mosquito breeding sites, household construction, household crowding and personal protection measures against mosquitoes (Clarke *et al.,* 2002). In turn, these factors are proximally influenced by differences in environmental landscape (Rejmankova, 1995; Thomas and Lindsay, 2000) and socio-economic status (Koram *et al.,* 1995; Clarke *et al.,* 2001). The relationship between environmental variables, socio-economic status and health is well known, for instance, a relationship between low socio-economic conditions and high mortality has been reported consistently in many different situations (Rosen, 1979). A full understanding of the influence of these factors is frequently hindered by a lack of detailed data relating to a full range of contextual factors together, most of which have not been extensively investigated.

This is particularly true for epidemic-prone areas in highland locations, despite the increasing interest in the epidemiology of highland malaria (Hay *et al.,* 2002). In these areas, transmission is unstable and the risk of disease tends to be equal across all age groups as populations have little or no immunity against Plasmodium spp. This study examined the determinants of clinical malaria infection among residents of Iguhu location, a rural area in the highlands of Western Kenya.

Materials and Methods

Study Site

The study was conducted at Iguhu location, 0° 17'N, 34° 74'E, at an elevation of 1,450–1,580 m above sea level in Ikolomani division, Kakamega County in Western Kenya (Figure 1). The annual average rainfall of 1,977 mm is seasonally bimodal, with the long rains occurring from March to June and the short rains from October to November. Average annual minimum and maximum temperatures are 13.8°C and 28°C, respectively. Malaria transmission is seasonal with peaks occurring 2–3 months after the peak rains in April–May, although the extent of the malaria burden varies considerably from year to year. The Yala River bisects the study site. The study area includes a mosaic of land use types (Mushinzimana, 2006). The hills are mostly maize land dotted by patches of tea plantation, and several swamps are found along the Yala river valley. The main economic activity of the area is agriculture, with the other economic activity being brick making on a small scale.
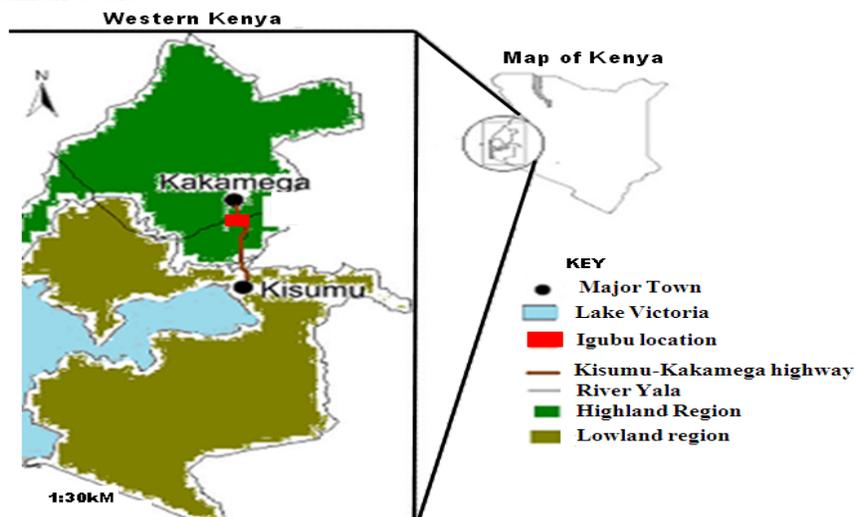

Figure 1: Iguhu Location, Kakamega District, Western Kenya (Mushinzimana, 2006)

Study Participants

A total of 300 clinical malaria cases were matched to 600 controls in the study, calculated using OpenEpi statistical technique, at 95% confidence interval with the ratio of controls to cases being 2.0 (Anonymous, 2009). Enrollment of participants in the study was voluntary following a written consent/assent form. Infants below five months and adults above 45 years were excluded from the study due to the difficulty in obtaining a clinical malaria case and age-matched controls within the same locality.

Selection of Clinical Malaria Cases

Clinical malaria case selection was conducted in the laboratory at Iguhu Hospital during the routine diagnosis of the out-patients. A finger prick blood sample was taken from each study participant from which a drop was placed on a slide. Both thin and thick blood smear were prepared from the drop of blood. The prepared blood smears were taken to Kenya Medical Research Institute (KEMRI) laboratory and stained using Giemsa for microscopic examination (Garcia, 1996). Participants with signs of clinical malaria such as vomiting, fever, chills and whose slides were malaria positive after examination of their thick blood smear were explained to the purpose and methodology of the study and enrolled in the study as clinical malaria cases following a written consent of the patient or patient's guardian if the patient was less than 18 years old. The thin blood smears of the enrolled cases were utilized in the actual count of parasitemia.

Selection of Non-Clinical Malaria Cases (Controls)

The home of each malaria case was visited to obtain a control of nearly the same age and within the same area of residence. The individuals were screened for parasite infection by obtaining a finger prick blood sample which was used to prepare both thick and thin blood smear. The blood smears were then taken to KEMRI laboratory where they were stained using Giemsa stain and examined microscopically to ascertain the presence and quantity of malaria parasites. The participants with no clinical malaria symptoms were recruited in the study as controls following a written consent or that of their guardians if the patient was less than 18 years old.

Blood Sample Processing and Identification of Malaria Parasites

The thin and thick blood smears collected in the field were air dried. The thin smears were fixed in methanol and stained in 4% Giemsa for 30 min. Two experienced technicians examined the slides under x- 1,000 oil immersions to identify and count the parasite species. Parasite density was scored against 200 leukocytes when the slide was positive; otherwise, the whole slide was carefully scanned before being declared negative. Parasite densities were

converted to number of parasites per microliter of blood, assuming a leukocyte count of 8,000 cells/µL (Munyekenye *et al.,* 2005). For quality control, 10% of the blood smears were randomly selected and read.

Household Survey
The altitude, longitude and latitude of the households of all study participants were determined using a hand-held Trimble GeoExplorer3 global positioning system (GPS). Observation was used to collect data on the household construction and the data recorded included the presence of eaves, screens, roof type, floor type, wall type and number of rooms in the house. A pre-tested questionnaire was orally administered to the household head or spouse of both clinical malaria cases and controls to ascertain socio-economic and behavioral characteristics such as number of occupants, level of education and occupation of household head and spouse and their health seeking behaviors.

Collection and Identification of Adult Mosquitoes
Pyrethrum spray collection was done to quantify the adult malaria vectors in the houses of the participants enrolled in the study. The occupants were asked to cover all their food stuffs and water and organize their houses. White cotton sheets were spread to cover the entire floor of the house and all openings including doors and windows closed. Using a spray pump containing 5 litres of paraffin, 5ml of permethrin and 6 ml of butoxide as recommended by WHO, the house was sprayed from the farthest room coming towards the entrance door (WHO, 2002). After a period of 10 minutes, which allowed for knock down of adult mosquitoes, the sheets were assembled on one common sheet and presence of any mosquito determined by observation. The mosquitoes were then collected and preserved in petri-dishes containing wet cotton wool and filter paper. They were finally taken to KEMRI laboratory for identification and classification as either males or females. Females were categorized into various gonotrophic stata which included: empty, blood-fed, gravid and half gravid female mosquitoes.

Data Analysis
Data analysis was restricted to a comparison of clinical malaria case and control groups by use of SPSS. For parasite and vector densities, t-test was used to test for any significant differences in their means at 0.05 level of significance (95% C.I.). For the analysis of the effect of abiotic factors on clinical malaria incidences, univariate analysis was conducted using logistic regression to estimate Odds Ratios (OR). Odds Ratios were then used to describe the strength of association or non-independence between the variables and clinical malaria infection. The p-values obtained were used to

explain the existence of any statistical significance in the variables in relation to clinical malaria. Based on the results of the univariate analysis and including variables with *P*-values < 0.05, a multiple-logistic regression model was developed to further assess the effect size of the significant variables.

Results

Parasite Density
A total of 300 clinical malaria cases were matched to 600 controls during the surveillance period. Malaria parasite density varied significantly among clinical malaria cases and controls (t = 1.99; df = 69; *P* < 0.0002). The cases had the highest parasite density (geometric mean of 6833.72 infected erythrocytes /μL blood, 95% C.I. 3.74 - 3.92) compared to the controls (geometric mean of 4018.45 infected erythrocytes /μL, 95% C.I. 3.44 - 3.77). This represented a 1.16 folds higher parasite density in the study group compared to controls.

Distribution of Malaria Cases
The GPS values of the elevations, latitudes and longitudes of all the clinical malaria cases and their corresponding controls were used to generate a map to study the distribution of the clinical malaria cases in Iguhu location (Figure 2).
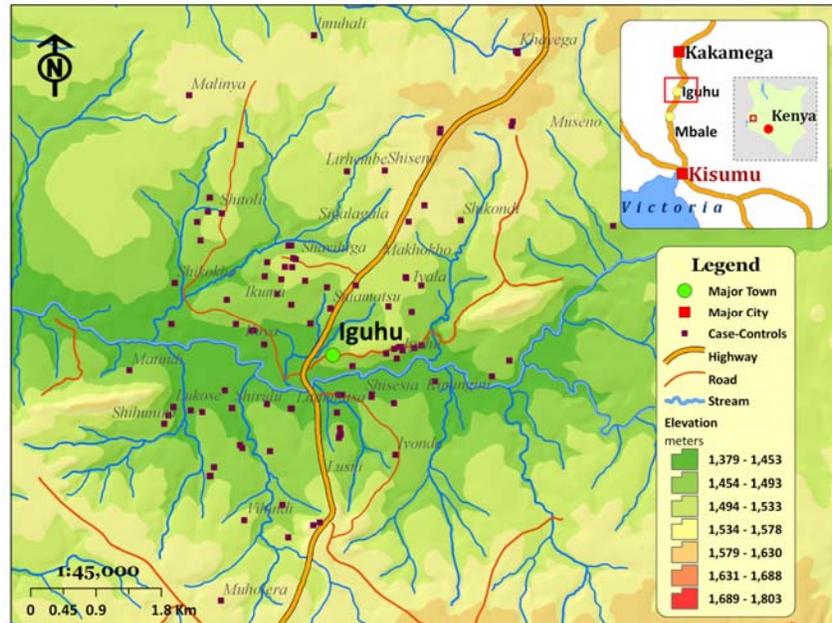

Figure 2: Distribution of clinical Malaria cases in Iguhu Location, western Kenya

Vector Density

The mean vector density (±SE) was higher in the houses occupied by clinical malaria cases (0.38 ± 0.058 vectors/house) compared to the houses occupied by the control groups (0.34 ± 0.078 vectors/house). In terms of mosquito vector species density, the mean density (±SE) of *Anopheles gambiae* was higher, 0.36 ± 0.057 vectors/house and 0.32 ± 0.075 vectors/house in the households occupied by clinical malaria cases and control groups respectively, compared to that of *Anopheles funestus*, 0.02 ± 0.009 vectors/house in the households of both clinical malaria cases and control groups (Figure 3).
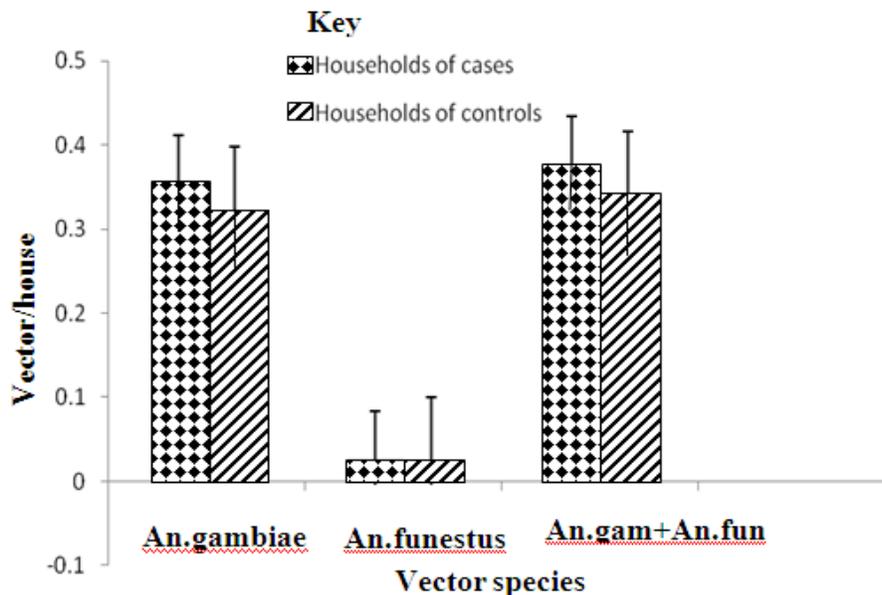

Figure 3: Mean density of vectors in the house holds of malaria cases and their controls

T-test for Equality of Means in Vector Population

Assuming unequal variances, there was no significant difference in the density of *Anopheles gambiae s.s* species in the households occupied by the clinical malaria cases and those occupied by the control groups (t= -0.130; df = 890; *P*-value = 0.897). There was also no significant difference in the density of *Anopheles funestus s.s* species in the households occupied by the clinical malaria cases and those occupied by the control groups (t= -0.129; df = 890; *P*-value = 0.898) and in the overall density of the total vectors between the households occupied by the clinical malaria cases and malaria controls (t= -0.108; df = 890; *P*-value = 0.914) (Table 1).

Table 1: T-test for equality of means in vector population

Vector	95% C.I.	t-test value	d.f	*P*-value
Anopheles gambiae	-0.199 – 0.174	-0.130	890	0.897
Anopheles funestus	-0.27 -0.24	-0.129	890	0.898
An. gambiae + An. funestus	-.202-0.181	-0.108	890	0.914

Gonotrophic Stata of Vectors

A higher density of blood fed vectors (0.38 vectors/house) were collected in the households of clinical malaria cases (0.22 vectors/house) and malaria controls (0.16 vectors/house) as compared to the density of the gravid vectors (0.14 vectors/house) in the households of clinical malaria cases (0.09 vectors/house) and malaria controls (0.05 vectors/house) and half gravid vectors (0.15 vectors/house) collected in the households of malaria cases (0.06vectors/house) and malaria controls (0.09 vectors/house) (Figure 4).
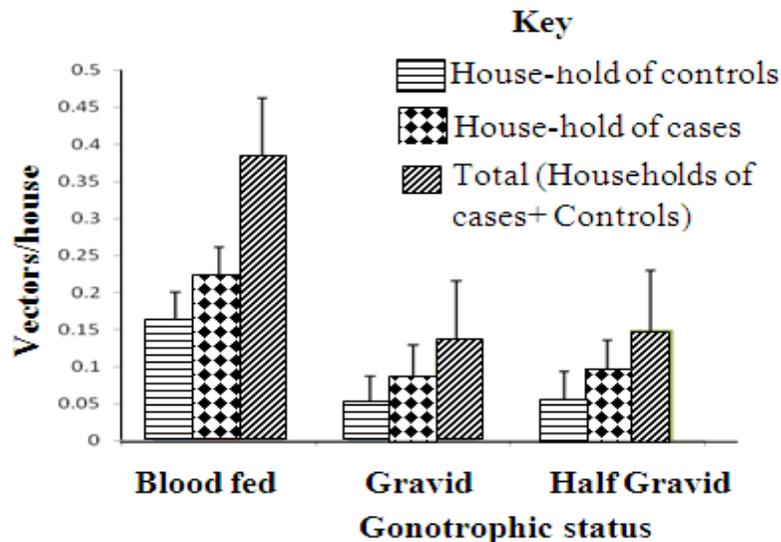
Figure 4: Mean density of different gonotrophic stata of vectors

Socio-Demographic Factors

During the study, 48% (n=145) of the clinical malaria cases surveyed were males while 52% (n=157) were females. The proportion of the controls matched to these clinical malaria cases was 46.7% (n=282) and 53.3% (n=322) males and females respectively. Also, 60.9% (n=184) of clinical malaria cases surveyed in the study were below 5 years compared to only 39.1% (n=118) of malaria cases aged 5 years and above. These were matched to 62.6% (n=378) and 37.4% (n=226) controls aged below 5 years and those aged 5 years and above respectively. The sex (O.R= 0.95; *P*-value

= 0.71) and the age (O.R= 1.07; *P*-value = 0.63) of the individuals were not significant determinants of malaria infection (Table 2).

Majority of the clinical malaria cases surveyed during the study period had their parents and/or guardians educated up to primary school level; 60.3% (n = 182) household heads and 65.6% (n = 198 spouses). However, only 1.3% (n = 4) of the clinical malaria cases and their corresponding malaria controls (2.0%; n = 12) had their parents and/or their guardians educated up to the tertiary level. In terms of education and occupation status, families whose spouses were employed (O.R = 0.43; *P*-value = 0.04) and educated up to secondary school level (O.R= 0.27; *P*-value < .0001) had lower chances of contracting clinical malaria. Though tertiary level of education was associated with reduced incidences of clinical malaria (O.R=0.45), this reduction was not statistically significant in the household head (*P*-value = 0.13), but statistically significant in the spouse (O.R=0.24; *P*-value = 0.01). On the other hand, the occupation status of household head (*P*-values 0.54; 0.25) and level of education (*P*-values 0.76, 0.35, 0.13) were not significant risk factors of malaria (Table 2).

During the study period, 61.3% (n=185) and 61.4% (n=371) of the households occupied by clinical malaria cases and malaria controls respectively had a population of 5 occupants and above. This was in contrast to 38.7% (n=117) households of clinical malaria cases and 38.6% (n=233) households of controls which were occupied by less than 5 occupants. However, household population had no significance (O.R = 0.99; *P*-value = 1.00) in the reduction of the incidences of clinical malaria (Table 2).

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Table 2: Odds Ratios for socio-demographic factors associated with the risk of Malaria

Variable		Cases	Controls	O.R	95% C.I	*P*-value
Female vs Males		52.0	53.3	0.95	0.72-1.25	0.708281
Adults vs children		39.1	37.4	1.07	0.81-1.42	0.631524
Occupation status						
Household Head	Farmer	47.0	49.7	1.20	0.68-2.11	0.537603
	Employed	46.7	42.4	1.39	0.79-2.46	0.254213
Spouse	Farmer	82.5	90.2	0.28	0.14-0.57	0.000212
	Employed	10.5	7.6	0.43	0.18-0.98	0.043138
Level of Education						
House hold head	Primary	60.3	44.7	1.16	0.45-2.99	0.764177
	Secondary	32.5	43.9	0.63	0.24-1.66	0.348202
	Tertiary	5.0	9.4	0.45	0.15-1.34	0.1267
Spouse	Primary	65.6	72.8	0.33	0.21-0.50	<.0001
	Secondary	13.6	18.0	0.27	0.16-0.47	<.0001
	Tertiary	1.3	2.0	0.24	0.07-0.80	0.014387
Household No: ($\geq$ 5 vs <5)		61.3	61.4	0.99	0.75-1.32	1.00

House-Hold Characteristics

During the study period, 89.7% (n=271) of the clinical malaria cases and 94.7% (n=572) of the controls lived in iron roofed houses. However, it was notable that 10.3% (n = 31) houses in the clinical malaria cases were thatched with grass compared to only 5.3% (n = 32) houses in the controls. Although the house roof was associated with a decrease in the risk of malaria (O.R= 0.46), this decrease was not highly significant (*P*-value = 0.0056) (Table 3).

Most families, 93.0% (n = 281), in clinical malaria cases stayed in houses constructed with mud walls compared to the 84.9% (n=513) in the controls. Only 7.0% (n = 21) of houses in clinical malaria cases compared to the 15.1% (n=91) in the controls were constructed using bricks or blocks. From the study, wall type had a significant decrease in the risk of clinical malaria (OR = 0.42; *P*-value = 0.00047) (Table 3).

Also, 95% (n = 287) of clinical malaria cases and 86.9% (n = 525) of controls lived in earthen floor houses. However, it was notable that only 5.0% (n = 15) of the houses occupied by clinical malaria cases had cemented floors as compared to the 13.1% (n = 79) in the controls. The floor of the

house had a significant decrease in the risk of clinical malaria (O.R = 0.35; *P*-value = 0.00016) (Table 3).

It was evident that 49.0% (n = 148) of the houses occupied by clinical malaria cases had open eaves compared to the 32.1% (n = 194) in the controls. Closed eaves were significantly associated with a decrease in clinical malaria (O.R= 0.46; *P*-value <.0001). Majority (99%; n = 299) of houses of clinical malaria cases had no screens, and therefore presence of screens was insignificant in the reduction of clinical malaria (O.R = 0.83; *P*-value = 1.00) (Table 3).

In the study, 90.1% (272)) of houses occupied by clinical malaria cases and 89.4% (n = 540) by controls had four rooms or less. In terms of malaria risk, the number of rooms in the house played no role in determining the incidence of clinical malaria (O.R= 1.07; *P*-value = 0.76) (Table 3).

Table 3: Odds Ratios for House-Hold characteristics associated with the risk of Malaria

Variable	Cases	Controls	O.R	95% C.I.	*P*- value
Iron-roof	89.7	94.7	0.49	0.29-0.82	0.005584
Permanent wall	7.0	15.1	0.42	0.26-0.69	0.00047
Cemented floor	5.0	13.1	0.35	0.20-0.61	0.00016
Closed eaves	51.0	67.9	0.49	0.37-0.65	<.0001
Absence of Screens	99.0	99.2	0.83	0.20-3.50	1.00
No. of rooms (≤ 4)	90.1	89.4	1.07	0.68-1.70	0.764177

Malaria Intervention Strategies

The ITNs were mostly used by the controls (64.6%; n = 390) compared to the clinical malaria cases (48.3%; n = 146). ITNs had a protective value in reduction of clinical malaria incidences (O.R = 0.51; *P*-value <.0001). The proportion of controls that used Indoor residual spraying (IRS), burning of herbs and mosquito coils was higher (63.1%; n = 381) compared to the clinical malaria cases (44.0%; n = 133). These mosquito prevention measures were significant in the reduction of clinical malaria incidences (O.R = 0.46; *P*-value <.0001).

Although prophylactic antimalarias were rarely used especially among clinical malaria cases (22.2%; n = 67) compared to the controls (45.7%; n = 276), these drugs significantly reduced clinical malaria incidences (O.R = 0.34; *P*-value <.0001) (Table 4).

In the study, 98.7% (n = 298) and 92.7% (n = 560) of clinical malaria case and control groups respectively resorted to government health facilities for medication while sick. However, the percentage of clinical malaria cases that resorted to private health facilities was lower (1.3%; n = 4) compared to the controls (7.3%; n = 44). The health facility from which malaria therapy was sought significantly reduced clinical malaria incidences (O.R= 0.17; *P*-value = 0.0002) (Table 4).

Table 4: Odds Ratios for Malaria and Mosquito prevention factors associated with the risk of Malaria

Variable	Cases	Controls	O.R	95% C.I.	*P*-value
ITN Use	48.3	64.6	0.51	0.39-0.68	<.0001
Malaria prophylaxis	22.2	45.7	0.34	0.25-0.46	<.0001
Mosquito prevention	44.0	63.1	0.46	0.35-0.61	<.0001
Health services sought (Private facility)	1.3	7.3	0.17	0.06-0.48	0.000159

Multiple Regression Analysis

Based on the results of the univariate analysis and including variables with *P*-values < 0.05, a multiple logistic regression model was developed. The risk of malaria was significantly reduced for families that used malaria prophylaxis and those whose spouses' occupation was farming. In families whose house hold spouses were not educated, the risk of malaria was high (Table 5).

Table 5: Logistic Regression Analysis of Significant variables associated with malaria risk

Variable	Estimate	S.E.	Lower Limit > 95%	Upper Limit 95%	Chi-square	Odds Ratio	Remarks
Intercept	0.656	0.41	-0.07	1.63	2.52	.	
Occ. HH (Not Farmer)	0.420	0.09	0.24	0.61	19.78	2.32	More malaria
Ed.Spo.(None)	0.308	0.13	0.06	0.56	5.82	1.85	
Open Eaves	0.270	0.09	0.10	0.44	9.39	1.72	
Use of firewood	0.920	0.38	0.29	1.85	5.90	6.31	
Mud walls	-0.866	0.25	0.25	0.69	13.40	7.06	
Roof	0.715	0.26	1.22	3.42	7.28	13.29	
Malaria prevention	-0.866	0.25	0.26	.691	29.73	1.31	
ITN use	0.666	0.14	1.47	2.58	21.94	1.45	
Occupation spouse (Farmer)	-0.363	0.12	-0.61	-0.12	8.65	0.48	Less malaria
Malaria prophylaxis	-0.516	0.09	-0.70	-0.34	30.76	0.36	

Key: Occ.HH-Occupation of House-hold head; Ed.Spo-Education status of Spouse

Discussion

In this study, epidemiological factors determining occurrence of clinical Malaria in the highlands of western Kenya were examined. The results showed that Malaria parasite density varied significantly among clinical malaria cases and their controls. It was found that most thick blood smears harvested from clinical malaria cases had malaria parasites. These parasites were responsible for the clinical malaria episodes in the active malaria cases, presented by symptoms like fever, chills, vomiting, headache and malaise. This was in contrast to the thick blood smears collected from the control groups, in which malaria parasites were detected on only a few slides. The presence of malaria parasites in the blood stream of some individuals without the corresponding clinical malaria could be attributed to the individuals' immunity.

The results from this study show that clinical malaria cases had 1.16 folds greater number of parasites in their blood as compared to controls. As a result, clinical malaria episodes were more frequent in the study group compared to the controls. The high parasite density among in the study group could be attributed to their close proximity to mosquito breeding habitats like swamps, streams and rivers like river Yala in the vicinity. This provides numerous efficient vectors which could spread the parasites within the human population. The low socio-economic conditions including inadequate use of insecticide treated nets, poor household construction; most of which are grass thatched, with mud walls, earthen floors and open eaves is likely to aggravate the parasite densities in the study group. On the other hand, the low incidence of infections among the control groups may be due to the comparatively higher standards of living, for instance, sleeping in an insecticide treated mosquito net, use of insecticides to spray their households, use of the recommended antimalarias; both prophylactic and therapeutic. Their houses are well constructed with iron roof, while some have cemented floors and walls.

The study area, Iguhu location, had numerous streams and water-bodies providing suitable breeding sites like streams and swamps for the vector. A previous study (Van der Hoek *et al.,* 1998) observed that houses located close to irrigated land, reservoirs, streams and canals tend to exhibit higher risk of malaria due to their close proximity to mosquito breeding sites. The results indicate that, more vectors were collected in the households of the study group compared to the households of controls. Of these, the density of *Anopheles gambiae* was higher compared to that of *Anopheles funestus*. These observations were similar to those made in the previous study which

showed that *Anopheles gambiae* and *Anopheles funestus* were the only malaria vector species in Iguhu and that the *Anopheles gambiae* was the predominant malaria vector species (Goufa *et al.,* 2007). The lower abundance of *Anopheles funestus* adults compared to the Anopheles *gambiae* may be attributed to lack of suitable, long-lasting larval habitats for *Anopheles funestus* because *Anopheles funestus* larvae normally take three weeks to develop into adults, and *Anopheles gambiae* larvae require approximately 10 days in sun-lit habitats (Malakooti *et al.,* 1998). Therefore, *Anopheles gambiae* larvae take a shorter time to develop into adults compared to the *Anopheles funestus* larvae. There was however no difference in vector density between study and control groups. The possible explanation for this observation is the close proximity of the houses of clinical malaria cases and their corresponding controls. For this reason, vectors could fly from one household to another in search of breeding sites. It's documented that *Anopheles gambiae* can fly to up to 10 km in search of breeding site (Kaufmann*,* 2004).

In this study, it was notable that a higher density of blood fed vectors were collected in the households occupied by the clinical malaria cases and malaria controls as compared to the density of the gravid vectors and half gravid vectors in the location. The higher population of blood fed vectors in the households was probably due to the rest taken by the vectors to allow the blood meal get digested and eggs in the ovaries mature. After resting and egg maturation, the vector is classified as gravid and begins searching for a suitable breeding site, preferably outdoors where it will lay its eggs (Hogg and 1997). This explains the decrease in the population of gravid and half gravid mosquitoes in the households of the residents in Iguhu location.

There was no difference in malaria infections by both age group and gender. As seen in a previous study (Brooker *et al.,* 2004), neither age nor sex was identified as significant risk factor for malaria infections in the current study. The possible explanation for this observation was that the proportion of males to females surveyed in this study was approximately equal. Also, both males and females of all age groups live under similar environmental conditions and under the same socio economic conditions and were hence exposed to similar factors for malaria infections. Therefore, there were equal chances of contracting malaria infection in the location, regardless of the age and gender status of the individual in question. It was however evident that majority of clinical malaria cases enrolled in the study were children aged below 5 years. A previous study (Tanner and Vlassoff, 1998) has shown that children aged below five years are more vulnerable to malaria infection compared to adults due to inadequate immunity in their systems to protect

them against the infection. Adults have had several exposures to the parasites and have since developed adequate protective immunity.

Majority of clinical malaria cases surveyed during the study period had their parents and/or guardians educated up to primary school level and very few had gone beyond this level. This could be due to their low socio economic conditions which limits the ability of families to afford higher education. Better education has been shown to reduce clinical malaria episodes in the location. Based on both univariate and multivariate results, the levels of education of spouses and their occupation status play a significant role in reduction of clinical malaria episodes in the location. Higher education confers an individual with the knowledge to recognize malaria and to treat it promptly and correctly. Findings elsewhere in Nigeria by Fawole and Onadeko (2001) demonstrated a statistically significant difference in the malaria 'knowledge score' of mothers of different ages, educational attainment and occupation. Knowledge was higher among those who were skilled or professionals than among the unemployed or unskilled category. In contrast, the occupation status and levels of education of household heads were not significant risk factors of malaria.

The household characteristics significantly affected mosquito abundance; hence mosquito bites and malaria infections. In this study, decreased parasitemia and hence malaria infection was associated with closed eaves, iron roof, brick-walls and cemented floors. Closed eaves reduce the number of mosquitoes entering a house. Metal roof and brick walls seem to be protective against malaria infections since they deny the blood fed mosquitoes the resting sites otherwise provided by mud walls and grass thatched roof. Cemented floors were associated with a lower risk of malaria. This is because cemented floors and permanent walls are associated with a higher economic status in a family due to the high cost of materials and skilled labour involved. The size of the house, in terms of the number of rooms, did not determine malaria incidence. This could be due to the fact that there was relatively little variation in the design of the houses in the study area since most houses have four rooms or less.

Our observations were in agreement with findings elsewhere that sleeping under bed nets is associated with protection against clinical malaria as it reduces mosquito bites (Hawley, 2003). In addition to this, other measures that keep mosquitoes at bay including regular use of insecticide sprays and mosquito coils, burning of herbs and use of fan were found to have a protective value against clinical malaria. It was found that prophylactic antimalarials were rarely in use among the study and control groups due to

the high cost of purchasing the drugs and their negative effects. However, these drugs could have a protective value in malaria infections and are particularly beneficial for short-term visitors and travelers to malaria endemic regions.

Conclusions

1. This paper reports findings on the prevailing "Epidemiological Factors that Determine Clinical Malaria in the Highlands of Western Kenya, a Case Study of Iguhu Location."
2. This was a case-control study in which risk factors associated with malaria in Western Kenya Highlands were evaluated. A simple Household survey of existing clinical malaria cases and their age-matched controls was undertaken to collect information on the potential exposure factors and socio-economic status. Mosquito samples were harvested from participants' houses for identification and cataloging. The parasite and vector populations in malaria cases and controls were determined using the "t-test".
3. The study reveals that sexes, age, household population, education level and occupation status of the household head were not significant determinants for clinical malaria.
4. In contrast, families whose spouses were employed and educated to tertiary level had lower incidences of clinical malaria.
5. Similarly, Use of ITNs prophylaxis and mosquito prevention measures were found to significantly reduce incidences of clinical malaria.
6. The study does provide some evidence that clinical malaria incidences in Western Kenya Highlands is likely to be influenced by both biotic and abiotic factors including parasite and vector densities suggesting that any successful malaria control program should be focused towards prevailing local conditions in a given area.

Recommendations

1. The fight against malaria should be accompanied by the fight against poverty and improvement of living standards.
2. Girl child education and women empowerment might be of importance in malaria intervention strategies.
3. Reduction of mosquito bites should be addressed through provision of insecticide treated nets (ITNs) and indoor residual spraying (IRS).
4. Government facilities should be well equipped with diagnostic equipment, drugs and enough health workers to serve the large local

population who seek medical intervention when they contract malaria and other infections.

5. There is need to generate more reliable information on infection risk, living conditions of concerned populations, and vectors to aid in control of malaria.

6. Further studies are required on the travel history, environmental factors and carriage of drug resistance genes among the population in the Highlands of Western Kenya to complement this study.

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