ORIGINAL ARTICLE

Malaria parasite species prevalence and transmission dynamics at selected sites in the Western highlands of Kenya

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ABSTRACT

Background: Malaria in the Western Kenya highlands is unpredictable sometimes leading to epidemics that result in dramatic emergencies in terms of severe morbidity and mortality. This places enormous strain on health facilities disrupting fragile health care services culminating into crises. This underlies the need for a better understanding of the disease dynamics and determinants to formulate specific and focused intervention strategies. **Aim:** One year study was undertaken in Kipsamoite and Kapsisiywa in Nandi County to evaluate *Plasmodium* species prevalence and transmission risk in the general population and specific age groups. **Subjects and Methods:** Positive blood smears were used to determine monthly malaria prevalence, age-group prevalence. Malaria risk in population was worked out using adult to child ratio (ACR). **Results:** ACR results indicated a less immune population in which all age groups and sexes were equally susceptible to malaria. *Plasmodium falciparum* was most prevalent (90%, $n = 264$) while *Plasmodium malariae* (10%, $n = 30$). There was significant difference in the malaria parasite species prevalence (χ^2, $P < 0.05$), but there was no significant difference in parasite species prevalence between the study sites (χ^2, $P > 0.05$). **Conclusions:** Malaria transmission dynamics were similar in both sites, largely driven by seasonality, had an even age distribution implying that the threat of epidemics was real should all age-groups become exposed to parasites and conditions of disease transmission become favorable.

Keywords: Adult to child ratio, disease dynamics, epidemics, prevalence, transmission

INTRODUCTION

Malaria transmission dynamics is highly variable throughout Africa. Transmission can occur throughout the year or only during a couple of months, with heterogeneities observed between years within the same locale.[1] Levels of human malaria transmission may be described as high, moderate, low, seasonal, perennial, or characterized by periodic epidemics and outbreaks.

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In the highland areas of Africa, malaria is a devastating disease with high mortality and morbidity demanding a rapid comprehensive response. In other settings, it can be a more pernicious public health threat than in others. In Kenya, nearly 7 million people translating into approximately 23% of the total population reside in 15 counties defined as highland malaria epidemic-prone areas.[2] Since the mid-20th century, epidemic malaria has been reported in the Western highlands of Kenya than any other part of the country.[3-8] The frequency and intensity of outbreaks increased significantly in

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first decade of the 21st century.[9,10] Even though there has not been any report of major outbreak in recent years, the forecast for the future is not favorable in this region. Malaria epidemics are most likely to be frequent and intense in future if the current intervention strategies and surveillance are not sustained, closely evaluated and monitored. Therefore, there is need for further search for more epidemiological determinants associated with general malaria transmission that could lead to evolution of epidemics in the Western highlands of Kenya.

The genesis of malaria epidemic in the Western highlands of Kenya is multi-factorial and may be related to the local vector species[11] climate and environmental changes[12-14] anti-malarial drug resistance[15] and decline in population immunity.[16] However, the contribution of each of these factors to any given epidemic is variable from year to year in different localities within the highlands. This is supported by the discovery of "malaria hot spots" within the Western highlands with unique epidemiological characteristics.[17] There is need to generate more information on possible factors that can lead to the genesis and propagation of malaria and epidemics in the highlands for appropriate malaria and epidemic control in future.

Most malaria epidemics in the Western highlands have been associated with a single *Plasmodium* species. There are reports that epidemics may occur by the superposition of any of the known malaria parasite species: *Plasmodium falciparum, Plasmodium ovale, Plasmodium malariae,* and *Plasmodium vivax*. The spread of such epidemics may involve several chains of transmission[18] such that a relatively large area may appear to show a single prolonged epidemic. These may actually be a number of overlapping local epidemics in different phases and associated with different malaria parasite species[19] and would require diverse intervention strategies. Whenever they occur, such epidemics present severe and serious public health problems in the highlands with disastrous consequences at individual, household, community, regional, and national level.[20]

In this regard, there is need for continuous assessment of the parasite species circulating in highland malaria epidemic-prone areas to have an idea on how fast or slow malaria transmission or epidemic can spread in the community. This together with early detection of community vulnerability and transmission risk indicators can be used to predict future epidemics, plan for a phased control response and allow organizations capacity to monitor and assess the situation before committing valuable resources.

The study seeks to determine the *Plasmodium* species, malaria prevalence and transmission stability at two malaria epidemic-prone study sites of Kipsamoite and in Nandi County. Previous studies indicated that malaria transmission occurs in "hot spots"[17] and is seasonal and sporadic in both sites.[21] Information on *Plasmodium* species prevalence and transmission dynamics at specific sites is limited in the Western highlands of Kenya. The study findings are likely to form basis for policy formulation on malaria prevention and control in the highlands of Kenya.

SUBJECTS AND METHODS

The study area and sites

The Kenya Western highlands are found at an altitude of 1500 m above sea level to the west of the Great Rift Valley including the following counties: Kisii, Kakamega, Kericho, Kakamega, Nandi, Trans-Nzoia and Bungoma. The study was conducted in Nandi County at two sites: Kipsamoite and Kapsisiywa selected because malaria epidemics and outbreaks had been reported within the sites previously and availability of two government run health centers where vast majority (>80%) sought medical care and therefore ideal sampling points.

Subject recruitment and ethical considerations

Ethical clearance was obtained from ethical committee at Kapsabet County hospital before the project started. The community at the study sites was sensitized to understand and appreciated the study objectives. Informed verbal or written consent was obtained from all those willing to participate or from their guardians before recruitment was undertaken. Included in the study were those who had been residents for a period of 6 months preceding study. Those excluded were nonresidents, pregnant women, those on anti-malarial treatment and those who declined to give informed consent.

Participants were recruited into the study between January and December 2014 by sampling carried out at 2 week intervals. Because the prevalence of malaria was not well known in the study area, a 50% estimate of the individuals attending the health centers was used for the patients who visited the health centers, which gave the best sample size used. Participant

recruitment was based on individuals presenting with and without malaria symptoms at health centers. Participant sampling from the study population was by a consecutive series of participants attending clinic until sample size was or the nearest figure to sample size was obtained.

Identification of *Plasmodium* species and determination of malaria parasitemia

Consenting individuals had 0.5–1.0 ml of blood obtained by the following procedure at the health centers: Preparation of site (finger) with alcohol, pricking of the fingertip with a lancet and obtaining the blood sample on a clean 25 mm × 75 mm slide in a 10–30 s period. The blood was spread out to make thick and thin smears, dried and fixed in methanol and stained in 4% Giemsa at recommended pH of 7.2 for 30 min.

All stained blood films were examined microscopically at 1000 × objective under oil immersion to for malaria parasites. Microscopic examination was done at the health centers and the presence of malaria parasite species sexual or asexual stages in thick blood smears was considered a positive diagnosis. A second and third blood examination reading was done by different technicians to ensure quality assurance. Thin blood smears were used for *Plasmodium* species identification. The whole slide was carefully scanned before being declared negative. Slides were reported negative for parasites only after examining at least 50 oil-immersion fields of the thick smears. An individual was defined as a malaria "case" if her/his blood smear was positive for *P. falciparum* or any other *Plasmodium* species known to cause disease in man. All individuals diagnosed with clinical malaria or positive blood films at the health centers were given treatment by the clinic staff according to the Kenya Ministry of Health guidelines.

Determination of malaria age prevalence and transmission stability

The ratio of adults positive for malaria to children positive for malaria designated as adult to child ratio (ACR) was used to determine the transmission stability as described elsewhere.[7] The ages of the subjects were stratified into the following age groups in years: <1, 1–4, 5–9, 10–14, 15–19, and >19.[22] Age specific prevalence was determined by expressing positive blood smears as a percentage of all examined smears (for the age group). The Chi-square test (χ^2) was used to determine the differences in prevalence among the age groups. Malaria transmission stability was determined by calculating the parasite prevalence in adult subjects (≥15 years) and child (≤15 years) as used by Simon *et al*.[7] The ACR of cases was calculated from total adult and child blood smear slide positive cases for the duration of the study period. Analysis of the malaria parasite species prevalence in the study sites was done using Chi-square statistic (χ^2) while malaria infection rates between the sites and among age groups was analyzed by ANOVA.

RESULTS

Malaria parasite species prevalence

A total of 3880 individuals (2650 from Kapsisiywa and 1230 from Kipsamoite) aged from <1 year and above including males, females were screened for malaria from January to December 2014. The positivity rates (parasite ratio) of infection for the different malaria parasite species is shown in Table 1. Chi-square analysis indicated a significant difference (χ^2, $P < 0.05$) between *P. falciparum and P. malariae* occurrence in the study sites. *P. falciparum* was the most prevalent malaria parasite accounting for 89.8% of the diagnosed cases in both study sites. *P. malariae* was recorded in both sites at low frequency and constituted 10.2% of malaria cases in Kapsisiywa and 9.8% in Kipsamoite [Table 1]. *P. malariae* was often seen in mixed infections with *P. falciparum*. No cases of *P. vivax* and *P. ovale* were detected. Malaria cases were more prevalent between the months of March to August during which about 95% of cases were recorded. The remaining 5% of the cases were detected in January and February. No malaria cases were recorded in October and December in both study sites.

Adult and child vulnerability to malaria

The results [Figure 1] demonstrate that ACR in the study area ranged from 0.5 to 1 with an annual average of approximately 1 implying that malaria in the area was unstable. This was interpreted that there was an equivalent malaria risk in both adults and children. It also suggests that there is no community-acquired immunity.

Table 1: *Plasmodium* prevalence and parasite species prevalence

Site	Samples screened	*Plasmodium*			Prevalence rate
		P.f +ve (%)	P.m. +ve (%)	Total +ve	
Kipsamoite	2650	172 (89.6)	20 (10.4)	192	7.2
Kapsisiywa	1230	92 (90.2)	10 (9.8)	102	8.2
Total	3880	264 (89.8)	30 (10.2)	294	

P.f +ve%: *Plasmodium falciparum* positive cases expressed as a percentage, P.m +ve%: *Plasmodium malariae* positive cases expressed as a percentage, Total +ve: Total positive cases

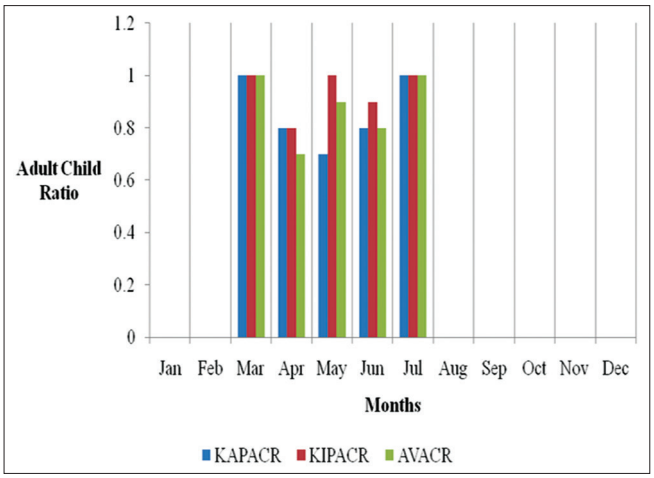

Figure 1: The adult child ratios for Kapsisiywa and Kipsamoite in 2014 (KAPACR = Kapsisiywa adult child ratio, KIPACR = Kipsamoite adult child ratio, AVACR = Average Adult child ratio in the two study sites)

The average ACR of 0.84 (almost unity) further supports an even distribution of disease in both adults and children in the study sites. The annual ACR distribution also indicated that most positive cases were detected in the months of March to July, corresponding to the rainy season in the study sites.

DISCUSSION

Globally, there are five *Plasmodium* species that cause human malaria. These are: *P. falciparum, P. malairae, P. vivax, P. ovale* and *Plasmodium knowlesi*. The distribution and relative abundance in Kenya of four *Plasmodium* species that cause human malaria is as follows: *P. falciparum* is the most common (80–85%), *P. malariae* (10–15%), *P. ovale* (<5%), and with *P. vivax* reported as infrequent.

Of the 294 confirmed malaria cases in the study sites, 89.6–90.2% were *P. falciparum* and 9.8–10% *P. malariae.* The relatively short extrinsic incubation period of *P. falciparum* could be a possible reason to explain why the parasite species is more common than the others. Neither *P. ovale* nor *P. vivax* infections were detected. These results are consistent with those of others from the same or neighboring areas. Beier *et al.*[23] in a similar study in the lowlands of Kenya found equally higher rates for *P. falciparum* and lower rates in the other three malaria species.

P. falciparum is the parasite species responsible for the most serious forms of malarial illness and for essentially all fatal cases of the disease worldwide. The species has been associated with frequent malaria outbreaks in the Western Kenya highlands in the past.[7,24-26] Since *P. falciparum* was the most prevalent in the present study area, efforts to limit mortality associated with it must be prioritized because of its potential fatal consequences. This suggests that any case of malaria encountered in the area and the study sites should receive effective treatment promptly and early enough to prevent severe disease, death, and spread. When *falciparum* malaria treatment is delayed or not given, there is danger of build-up of chronic infections in the population that eventually spread by the long-lived largely anthropophilic *Anopheles gambiae* vectors leading to outbreaks and possibility of epidemics.[27-30] In a related study, in Western Kenya, Shanks *et al.*[31] key recommendation was to cure enough *falciparum*-infections to halt parasite spread during seasonal transmission. In this regard, the choice of the first line malaria therapy is crucial to cure those infected, as well as allow maximum number of persons to get access to free treatment.

The average calculated ACR ratios approximated unity, suggesting that malaria risk in childhood was comparable to that in adults (there were equivalent risk in children and adults). Such high ACR ratio indicates a less immune population in which both adults and children become symptomatic when infected with malaria parasite. In a related study in Uasin Gishu at an altitude of 2134 m, in Western Kenya, John *et al.*[10] found no difference in re-infection rates between children and adults indicating that transmission was unstable at that altitude.[32] This findings contrast with the age-related protection from infection reported in areas of stable, intense transmission.[33] It also demonstrates that areas of infrequent parasite exposure lend themselves to equivalent risk in adults and children.[7] This suggests an increasing tendency toward unstable malaria transmission, assuming that there were no age-dependent biases in clinic attendance rates at the sites.

The disease instability may further be explained by the hill valley topography common in the Western highlands. It is suggested to have an effect on malaria transmission intensity ranges from low to high.[34] In this regard, human settlers in the valley bottoms (near vector breeding sites) may serve as "malaria reservoirs," experience more infective bites and they develop some degree of immunity to the severe consequences of malaria infection. This is the opposite of the human population uphill, which is not exposed to malaria infection regularly and generally lacks immunity to malaria because exposures are infrequent.[9] Therefore,

the difference in exposure to infective bites of the general population may be the cause of disease transmission instability in this study sites and indeed in the entire Western highlands.

The discovery of clustered "hotspots" (defined as areas of high malaria incidence within an epidemic-prone area/clusters of cases of malaria within an epidemic prone zone) in study sites[17] could also explain the observed malaria transmission instability trend. The determinants of such clustered transmission spots are likely to be due to shared anthropogenic and environmental variables, as well as factors related to contagion such as population density and human settlements.[29]

In a related study,[35] findings demonstrated that there was spatial clustering of malaria cases in children during an epidemic in a single year in a highland area of Kenya. However, without sufficient data for several years, it is difficult to discern if the clusters of cases are transient or if they relate to more long-standing foci of infection that may affect the entire study area. The recognition of consistent foci of abundant vectors or malaria cases would permit focused control efforts to be directed at specific sites, reducing costs, and increasing effectiveness.[17]

The present epidemiological situation in the Western highlands may not remain so for long, because climatic change, topography, human settlement pattern, land use, and drug resistance may change the situation.[9] Climatic conditions influence the development, reproduction, and survivorship of anopheline mosquitoes and malaria parasites.[25] Topography and human settlement patterns affect the spatial distribution of vector mosquitoes and susceptible and immune populations.[36] Land use changes can cause the environmental conditions to be more favorable for the development and reproduction of mosquitoes and parasites.[37] Emergence of drug resistance aggravates malaria case fatality and enhances spread of resistant strains of parasites.[38] Therefore, future effective malaria control in the entire Western highlands will require an elaborate understanding of the interactions between and among these epidemiological factors.

CONCLUSION

The most prevalent malaria parasite were *P. falciparum* and *P. malariae* Malaria parasite transmission was unstable and seasonal suggesting that residual immunity to disease diminished with time or did not develop with time. Based on these findings, malaria in the sample population had an even age distribution implying that the threat of epidemics was real when parasites are introduced and conditions of disease transmission become favorable.

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Conflicts of interest

There are no conflicts of interest.

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