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Relationship between malaria and filariasis transmission indices in an endemic area along the Kenyan Coast

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Abstract

Background & objectives: An entomological survey was conducted to determine the relationship between malaria and lymphatic filariasis transmission by *Anopheles gambiae s.l.* and *An. funestus* in two inland villages along the Kenyan coast.

Methods: Mosquitoes were sampled inside houses by pyrethrum spray sheet collection (PSC). In the laboratory, the mosquitoes were sorted to species, dissected for examination of filarial infection and the anophelines later tested for *Plasmodium falciparum* circumsporozoite proteins by an enzyme-linked immunosorbent assay (ELISA).

Results: From a total of 2,032 female mosquitoes collected indoors, *An. gambiae s.l* constituted 94.4% while the remaining 5.6% comprised of *An. funestus* and *Culex quinquefasciatus*. None of the *Cx. quinquefasciatus* was positive for filarial worms. *P. falciparum* sporozoite rate for *An. gambiae s.l.* from both villages was significantly higher than *Wuchereria bancrofti* infectivity rate. Similarly, the entomological inoculation rate for *An. gambiae s.l.* was significantly higher than the corresponding *W. bancrofti* infective biting rate and transmission potential for both the villages. Mass treatment of people with filaricidal drugs in Shakahola in the ongoing global elimination of lymphatic filariasis campaign seemed to have reduced the indices of filariasis transmission but had no effect on malaria transmission.

Interpretation & conclusion: These results indicate the intensity of malaria transmission by anophelines to be much higher than that of lymphatic filariasis in areas where both diseases co-exist and re-emphasise the need to integrate the control of the two diseases in such areas.

Key words *An. funestus* – *An. gambiae s.l.* – Kenyan coast – *Plasmodium falciparum* – transmission – *Wuchereria bancrofti*

Introduction

Malaria and lymphatic filariasis (LF) are Africa's most important vector-borne diseases. Current estimates indicate that 90% of the 1.5–3 million deaths due to malaria occur in Africa[1] and over one-third of the 146 million people infected with LF are from this continent[2]. In rural areas of the Kenyan

coast, both diseases co-exist in the same human populations with *Anopheles gambiae s.s., An. arabiensis* and *An. funestus* (Diptera: Culicidae) playing the dual role in their transmission[3, 4]. In addition, *Culex quinquefasciatus* (Diptera: Culicidae) initially considered an urban vector of LF has also been shown to be an equally important vector in rural settings[4, 5]. Thus most communities in these areas are at continued risk of contracting and experiencing the morbidity associated with both diseases.

Despite the co-endemicity of malaria and LF in the same human communities and the sharing of common vectors, control programmes have been targeting each disease, individually, operating in a "vertical" orientation with little concern for other health problems in the same area[6]. However, the World Health Organization, Regional Office for Africa is currently implementing a new framework for vector control based on a strategy of integrated vector-management targeting both diseases simultaneously. This strategy is perceived not only to be cost-effective[7] but also feasible and has received a boost from successful results of insecticide-treated bednets against malaria and LF vectors[3, 8-10]. Moreover, a combination of albendazole and ivermectin currently used in the ongoing global programme for elimination of lymphatic filariasis (GPELF) has been reported to have an added advantage of reducing the burden of intestinal helminthes in children[11] and this corresponds positively with their school performance[12]. These findings demonstrate that the integrated control of parasitic infections is possible.

The first step towards designation and implementation of an integrated, simultaneous attack against malaria and LF would be to understand their local transmission characteristics. Studies in India[13] and South America[14] have demonstrated the occurrence of malaria and LF in the same human hosts. A similar study in Papua New Guinea reported the occurrence of multiple infections of malaria and LF in mosquitoes[15]. Our preliminary findings along the Kenyan coast revealed the occurrence of concomitant infections of malaria and LF both in humans and in mosquitoes[16]. Although we did not observe any significant interaction between malaria and filarial parasites in humans, *Wuchereria*-infected *An. gambiae s.l.* had significantly higher *Plasmodium falciparum* sporozoite rate than non-infected mosquitoes. However, concurrent transmission of such infections appeared rare, presumably due to reduced survival rates of mosquitoes. We therefore, hypothesised that differential control of either malaria or LF would reduce the number of mosquitoes carrying mixed infections of the two diseases thereby increasing their survival rates. This would in turn result in increased transmission of the other disease and hence, the need for integrating the control of the two diseases. The aim of the current study was, therefore, to compare the relationship between the intensity of malaria and LF transmission by anophelines in an area endemic for both the diseases in Malindi, Kenya. The results provide important baseline information necessary for designation and implementation of the currently advocated integrated disease control strategy.

Material & Methods

The study was conducted in Shakahola and Jilore villages in Malindi district in coastal, Kenya between September 2002 and February 2003. The study area and the sampling design have been described in details elsewhere[16]. In brief, the study area is hot and humid all year round with the annual mean temperatures ranging between 22.5 and 34°C and the average relative humidity ranging between 60 and 80%. Rainfall is bimodal with the long rainy season between April and June and the short spell during October–November. The population is mainly composed of the Giriama, one of the nine tribes of Miji Kenda occupying the Kenyan Coast. Giriama houses are palm-thatched huts with mud walls and no ceiling. Domestic water in both villages is collected from the permanent Sabaki River. In Jilore,

there is a small lake called ' Lake Jilore' where some fishing is carried out. Hospital records indicate malaria due to *P. falciparum* to be an important health problem in both villages, and accounted for 40.5 and 29.5% of the total clinical cases in Jilore and Shakahola, respectively in the year 2002[17]. However, the field entomological and parasitological indices of malaria transmission in the two villages are unknown. Lymphatic filariasis is also endemic in both villages as depicted by the high number of people with overt symptoms of the disease (Mwandawiro, personal communication). Currently, there is an ongoing LF control programme in Shakahola, while in Jilore there has never been any LF control programme. Five months before the commencement of this study, all the inhabitants in Shakahola village had taken the first annual single dose combination of di-ethylcarbamazine (DEC) and albendazole drugs. The prevalence of micro-filariaemia in humans before treatment was 17.7% while the filarial infectivity rate was 3% in *An. gambiae s.l.* and 1% in *An. funestus* (Mwandawiro, unpublished report).

Mosquitoes were sampled indoors by pyrethrum spray sheet technique[18] between 0700 and 1000 hrs. Due to logistical difficulties sampling in the two villages was uneven. In Shakahola, mosquitoes were collected in each of the ten houses once in a month over a three-month period namely; September 2002, and January and February 2003. In Jilore, the collections were done over a 6-month period between September 2002 and February 2003. All the mosquitoes were identified morphologically to species using taxonomic keys[19]. The head, thorax and abdomen of each *An. gambiae s.l.*, *An. funestus* and *Cx. quinquefasciatus* mosquitoes were put on a slide, macerated separately in a drop of phosphate buffered saline (pH 7.4) and examined under a compound microscope for filarial worms[20]. The number of larvae were counted to determine the infection load per mosquito. The debris of each dissected *Anopheles* mosquito was then preserved individually in plastic vials and later tested for *P. falciparum* circumsporozoite proteins using ELISA[21].

The indices of malaria and LF transmission were calculated according to Bruce-Chwatt[22], Bushrod[20] and World Health Organization[23]. The sporozoite rate was taken as the proportion of mosquitoes positive for *P. falciparum* sporozoites out of the total number of mosquitoes tested. The daily human biting rate (HBR) was obtained by dividing the total number of blood fed and half gravid mosquitoes caught in a house by the total number of people who slept in that house the night preceding collection. The product of the average daily HBR and the number of days in the 3-month and the 6-month sampling period in Shakahola and Jilore, respectively yielded the HBR for the entire sampling period. The entomological inoculation rate (EIR) for the same period was derived as the product of HBR and sporozoite rate.

Filarial infectivity rate was calculated as the proportion of mosquitoes carrying at least one infective (L_3) larva while the infective biting rate (IBR) was derived as the product of the HBR and filarial infectivity rate. Worm load, the average number of worms per infective mosquito was calculated by dividing the total number of infective larvae by the number of mosquitoes carrying infective larvae. The transmission potential (TP) was derived as the product of worm load and the IBR.

Data were entered into the computer using the FoxPro programme and analysed using SPSS software (version 11 for widows, SPSS Inc., Chicago, IL). The differences in malaria and filariasis transmission indices in each village were compared by independent sample t-test. Results were considered significant, when $p < 0.05$.

Results & Discussion

Three vector species—*An. gambiae s.l.*, *An. funestus*, and *Cx. quinquefasciatus* were collected in the study

Table 1. Entomological parameters for the transmission of malaria and Bancroftian filariasis in Jilore and Shakahola villages in Malindi, Kenya

Village	Species	No. dissected	Proportion infective for filarial worms	HBR	IBR	Worm load	TP	SP	EIR
Jilore	*An. gambiae s.l.*	1734	0.011	768.4	8.5	3.8	32.1	0.077	59.2
	An. funestus	58	0.017	116.8	2.0	1.0	2.0	0.017	2.0
Shakahola	*An. gambiae s.l.*	185	0.005	463.1	2.33	1.0	2.4	0.059	27.33
	An. funestus	2	0	–	–	–	–	0	–

HBR: Human biting rate; IBR: Infective biting rate; TP: Transmission potential; SP: Sporozoite rates; EIR: Entomological inoculation rate.

area. *An. gambiae s.l.*, and *An. funestus* harboured both malaria and filaria infections while none of the 53 *Cx. quinquefasciatus* collected was positive for filaria infections. Table 1 shows the entomological indices for the transmission of malaria and Bancroftian filariasis by *An. gambiae s.l.* and *An. funestus* in two villages. In Jilore, the HBR for *An. gambiae s.l.* (n = 1,734) over the 6-month period was 768.4 while that of *An. funestus* (n = 58) was 116.8. The corresponding value in Shakahola over the 3-month period was 463.1 for *An. gambiae s.l.* (n = 185). HBR for *An. funestus* was not estimated in Shakahola because only two specimens of this species were captured. Based on EIR and TP results, *An. gambiae s.l.* was the main vector of malaria and LF in two villages over the sampling period, with *An. funestus* playing a secondary role. The sporozoite rate for each village was significantly higher than the corresponding infectivity rate ($t = 9.593$ and 2.945, $p < 0.05$). The EIR of 59.15 for *An. gambiae s.l.* in Jilore was 7-fold higher than the corresponding LF IBR, whereas in Shakahola, the EIR for *An. gambiae s.l.* was 27 and 12-fold higher than the corresponding IBR. The overall EIR value for Jilore was 2-fold higher than the transmission potential (TP) whereas in Shakahola, the EIR value was 12-fold higher than that of TP ($t = 9.867$ and 3.095, $p < 0.05$).

This study identified *An. gambiae s.l.* to be the main vector of *P. falciparum* and *W. bancrofti* in the study area with *An. funestus* playing a minor role. Each individual from the two villages receives a single malaria-infective bite from *An. gambiae s.l.* every three days compared with 91 days for *An. funestus* in Jilore. Similarly, an individual receives a single infective bite from *An. gambiae s.l.* every six days in Jilore and every 39 days in Shakahola compared with 91 days for *An. funestus*. These results are within the range that have been reported previously along the Kenyan coast[3-5], and indicate that the intensity of malaria and LF transmission is species-specific. We did not, however, attempt to compare the transmission indices for the two villages because the sampling effort for the two villages was unequal due to logistical difficulties, making the samples for the two villages incomparable. We, therefore, treated each village separately and by doing so we are conservative in reporting the site-to-site variation in indices of transmission by *An. gambiae s.l.* and *An. funestus* although it appeared evident and has also been reported previously[4,5]. Moreover, we were unable to implicate *Cx. quinquefasciatus* with LF transmission in the study area despite previous reports that it is equally an important vector in rural areas of coastal Kenya[5].

The study indicates that although *An. gambiae s.l.* played the dual role in transmission of *P. falciparum* and *Wuchereria bancrofti*, the intensity of malaria transmission (*P. falciparum*) was higher compared to that of LF transmission. Transmission indices for malaria were higher than those of LF in both the

village. It is known that the latent period of *W. bancrofti* in the vector is usually long in relation to the vector life expectancy[24]. In contrast, the extrinsic cycle of malaria parasites lasts 9–10 days but can sometimes last for only five days[25]. Consequently more filarial-infected mosquitoes than malaria-infected ones are likely to die before the parasites mature to the infective stage. A support for this is seen in our previous work in the same study area where 17 mosquitoes harboured both *P. falciparum* sporozoites and immature stages of *W. bancrofti* while only two had sporozoites and infective larvae[16]. Moreover, Maxwell *et al*[26] argue that mosquitoes sampled using knockdown spray collection, are likely to yield fewer mosquitoes with infective larvae of *W. bancrofti*, as most infective larvae are lost during feeding. However, the number of infective mosquitoes caught by knockdown spray collection did not differ significantly from those of the human landing catches[5].

Our results indicate that although one round of mass administration of filaricidal drugs may significantly reduce the intensity of LF transmission, it has no effect on the intensity of malaria transmission. In Shakahola where mass administration of DEC and albendazole had been conducted five months before the present study, the EIR was 12-fold higher than that of filariasis TP. These findings are consistent with those from Papua New Guinea, where one round of mass administration of DEC alone reduced the ATP of *Anopheles*-transmitted *W. bancrofti* by 76–79% and microfilariae intensity by 64–75%[27]. Previously, we have documented that in areas where the two diseases co-exist, the life span of *An. gambiae s.l.* mosquitoes that pick-up both parasites concurrently seem to be greatly reduced to allow for simultaneous transmission of the two parasites[16]. Similar observations have been reported in *An. punctulatus* in Papua New Guinea[15]. Thus, control of LF alone may result to an increase in mosquito survival probability resulting to intense transmission of malaria. These findings support the need for integrated control of two diseases. Currently, the roll back malaria (RBM) partnership aims to ensure that malaria is no longer a public health problem by 2025, while the global programme to eliminate lymphatic filariasis (GPELF) aims to achieve a similar result for LF by 2020. Since the two diseases share common vectors, some synergy between the two programmes not only seems feasible and cost-effective but will also ensure that vector control, which is currently not well defined in GPELF as it is in RBM, becomes an integral part of LF control.

Due to logistical difficulties we were unable to conduct blood meal analysis and identification of sibling species of *An. gambiae s.l.* We assumed that all blood fed and half gravid *An. gambiae s.l.* and *An. funestus* mosquitoes collected had taken their blood meals from humans. Previous studies along the Kenyan coast have reported a high human blood index among *An. funestus* and the three sibling species of *An. gambiae* complex occurring along the Kenyan coast—*An. gambiae s.s., An. arabiensis* and *An. merus*[28,29]. The proportion of *An. gambiae s.l.* sibling species in these areas has been reported to be 81.9, 12.8 and 5.3% for *An. gambiae s.s.*, *An. arabiensis* and *An. merus*, respectively[4].

In conclusion, this study has evaluated the intensity of malaria and LF transmission along the Kenyan coast. The results indicate that the intensity of malaria and LF transmission is species-specific. The results further demonstrate that in areas where the two diseases co-exist and share common vectors, the intensity of malaria transmission is higher than that of LF transmission. In addition, these findings demonstrate how differential control of LF may impact negatively on malaria transmission as a result of increased survival of vector mosquitoes. There is, therefore, an urgent need to adopt an integrated control of the two diseases in areas where they co-exist, taking into account the local transmission characteristics.

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