Abstract

Rationale

Malaria prevention and control can be attained through a combination of strategies, including vector control, responsive health systems for prompt and accurate diagnosis and treatment, community access to information and interventions, and well-financed malaria control programmes. Disease prevention and control programmes depend mostly on the nature of disease transmission; therefore, this research (together with other research) helps to determine appropriate measures to prevent the target populations from the risks of acquiring infection. Historically, malaria control strategies had focused on indoor malaria transmission, with interventions aimed at reducing transmission from an endophilic and endophagic vector. In general, frontline interventions to reduce risk and prevent transmission included long-lasting insecticide Nets (LLINs) and insecticide residual spraying (IRS) but also prompt diagnostic tests and treatment. As a result of the roll-out of these strategies, many countries have experienced a tremendous decrease in malaria transmission, giving them hope to consider the possibility of malaria elimination.

Outdoor malaria transmission has always existed in forests, fields, and around houses and animals, depending on vector species and preferred habitat, behaviour and host availability (animal or humans). Notably, there has been an increase in malaria transmission as a result of the increased outdoor host-seeking behaviour of mosquitoes that previously fed indoors. This has been associated with an increased proportion of malaria mosquitoes biting outdoors, resistance to pyrethroids (commonly used on ITNs/LLINs) occupational factors including migratory farming activities and changes in land use. The change in vector habitat and behaviour, and consequent sustained transmission of malaria, is a growing public health concern that jeopardizes existing vector control strategies in malaria-endemic countries including those in Africa. Although there has been growing advocacy for new research on vector control and interventions, minimal consideration has been given to the contribution of human practices and behaviour to outdoor malaria transmission. Feasible malaria prevention and control programmes need integrative approaches that take into account all contributing factors to the risks of malaria transmission, both indoor and outdoor, and the allocation of appropriate and effective interventions.

In Tanzania, most malaria prevention and control programmes depend on donor funding and have focused on the prevention and control of malaria indoors. Despite research findings that indicate insecticide resistance and increasing outdoor biting by malaria vectors, outdoor malaria transmission has not been addressed within the aim and strategies for malaria control nor incorporated into the current strategies of the National Malaria Control Programme (NMCP). This reluctance to address “outdoor malaria transmission” is likely because it is a relatively new phenomenon and there are few funds available to be dedicated to interventions for preventing outdoor malaria transmission .

This doctoral dissertation addresses some of the factors driving outdoor malaria transmission in areas where frontline interventions such as LLINs are widely used. I hypothesize that community knowledge on outdoor malaria transmission and prevention, and a range of behaviours and practices,

might contribute to risk of infection. The four broad aims of this PhD project were to describe and analyse: community perceptions on outdoor malaria transmission; the interventions that people use while outdoors; the activities and practices that people undertake outdoors that expose them to mosquito bites; and the reasons for such practices being conducted outdoors.

Methods

The study was conducted in four villages in Kilombero Valley (two villages from each of the two districts Kilombero and Ulanga, from February 2015 to September 2016. A mixed method study was undertaken, based on a convergent parallel design approach whereby both qualitative and quantitative data collection strategies were conducted concurrently in the same phases of the research process. The mixed methods included entomological collections of mosquitoes by using modified CDC light trap and miniaturized double net trap (DN-Mini), and a range of social research methods to provide data to allow for indepth understanding of this topic. Specifically, in addition to observations of community activities and informal conversations with participants from the study communities, a) 40 in-depth interviews were conducted, with ten respondents selected from each village, b) eight key informant interview were conducted, with leaders/respected individuals from the community, and c) focus group discussions which were conducted with members of the study communities. Semi-structured interview guides were used to conduct all the in-depth interviews (IDIs), key informant interviews (KII) and focus group discussions (FGDs) (see guides at the end of the main texts). The interview guides were used to guide the researcher/data collectors during the conversations with adults/heads of selected household, leaders of the community and wider population respectively, to capture people's knowledge, perceptions, and attitudes toward outdoor malaria transmission.

Collection of entomological data was done by using the Centres for Disease Control and Prevention (CDC) light traps. However, the use of CDC light traps was not very efficient for indoor-outdoor biting risks comparisons so the data were complemented by additional mosquito collections using a miniaturized double net trap (DN-Mini). Mosquito biting rates of all *Anopheles* species collected were analyzed, and logistic regression (LR) was performed separately for each *Anopheles* species to determine the rate of exposure to the risk of malaria transmission as per identified activities. Using graphing and analysis in R statistical software, mosquito biting rates were analysed with the use of generalized linear mixed-effects models (GLMM) separately for each species, accounting for both fixed and random factors, with log-linked Poisson error distribution, using the *lme4* package in R statistical package. A structured observation guide was also used to document all activities that were conducted outdoors, and their frequencies were correlated with the host-seeking mosquitoes collected. Mosquito collection was conducted parallel to documentation of human outdoor activities hourly from 6:00 pm to 7:00 am. To assess community knowledge, identify interventions used and activities and practices in which people engaged, thematic content analysis was used for all interviews and focus group discussions, and for notes from observations, with themes identified and responses assessed as per identified themes.

Key Findings

The results show that there is limited knowledge on outdoor malaria transmission among people in the study villages. The emphasis on adherence to interventions has concentrated on the prevention of indoor transmission through the use of frontline interventions. The main sources of information on the prevention of malaria, which still focuses on indoor malaria transmission, are information from healthcare workers in hospitals, road and radion advertisements, fliers, and media broadcasts by the National Malaria Control Programme (NMCP) in collaboration with different donors. Prevention of outdoor malaria transmission is not included in the strategies for malaria prevention within the NMCP. While everyday domestic activities take place outdoors throughout the year, other outdoor activities such as celebrations occur seasonally and are associated with different religious, social and cultural purposes. Those that take place on a daily basis at the household level expose people on a continuing basis to outdoor mosquito biting, thus increase the risks of malaria transmission. The study results show that peridomestic activities are conducted outdoors during the evening when the host-seeking mosquitoes (malaria vectors including both *Anopheles Gambiae s.l* and *Anopheles funestus*) were collected are prevalent and actively biting. The seasonality catch of host-seeking mosquitoes indicates that during the dry season, the highest biting peak was observed among *An. gambiae s.l.* at 20:00 hrs while among *An. funestus* the highest peak was observed at 21:00hrs. During the wet season the highest peak biting time among *An. gambiae s.l.* was observed at 22:00 and 19:00hrs, but there was very limited amount of mosquito density. For *An. funestus,* the biting rate was low throughout the night with a slight peak between 22:00hrs and 0:00hrs. When comparing biting patterns indoors and outdoors, the study found that during the dry season, the biting rates for *An. gambiae* indoor started to peak at 19:00hrs with the highest peak at 21:00hrs, while for *An. funestus* there was steady biting pattern with a slight increase between 2:00hrs and 3:00hrs. During the wet season, the biting rate among *An. gambiae s.l.* started to peak at 19:00hrs with highest peak at 22:00hrs hours, when there was a very limited amount of human activities indoors, while among *An. funestus* the biting rates were still low with a slight increase at 22:00hrs hours to 0:00hrs, again, when there was a very low frequency of human activity indoors since some families sleep around 21:00hrs to 22:00hrs. Activities that took place at these times exposed people to the risk of mosquito bites; frequent exposure increased their risks of infection.

Seasonal, cultural gatherings and ceremonies are mostly conducted outdoors during the times when the host seeking mosquitoes are actively outdoors. During these activities and ceremonies, people hardly use interventions to prevent themselves from mosquito bites, thus putting people at risk of malaria infection and transmission. Although most gatherings are conducted during the dry season when there is lower vector density, gatherings associated with mourning and funerals are conducted year-round. The wet season has high mosquito density, so the risks of being bitten and infected are particularly high during this period. Attending social gatherings and ceremonies is of great importance to people in the study communities, and their engagement maintains unity, cooperation and social cohesion. There is poor access to interventions that can be used outdoors, despite the growing evidence of increased outdoor feeding and the risks of outdoor malaria transmission. House structures characteristically have minimal or no amenities like kitchens, bathrooms, and living rooms, this contributes to spending more time outdoor conducting activities such as cooking, eating, resting,

conversing and, above all, socializing. Houses have poor ventilation and during the dry season, when the ambient temperature is especially high, the houses become very hot due to the absence of ceiling boards indoors. People often find it unbearable to spend time indoors, and so people spend most of their time outdoors. Additionally, most houses have unscreened windows, eaves, and doorways, thus allowing mosquitoes easy entrance into houses; this contributes to the risk of exposure to mosquito bites indoors.

Implications

Minimal knowledge of outdoor malaria transmission risks and little or no consideration of risk or prevention of infections contributes to people's exposure to mosquito bites outdoors. Lack of attention to aspects of outdoor malaria transmission by the NMCP further hinders the integration of appriopriate strategies for malaria prevention and control. The NMCP continues to be silent on integrating these risks in malaria prevention strategies, and this jeopardizes the reduction and elimination of malaria in the country. In the study community, cultural and religious gatherings for both Christians and Moslems were conducted outdoors, but this is less significant than the changes in host-seeking mosquitoes and increases in outdoor biting, which continue to put people at risk of malaria infections year round. Social practices that involve communities, during a range of celebrations bring about socialization, improve unity and cooperation, and provide members of the community with material and financial benefits. These practices enable the study community to maintain social cohesion. Such activities cannot be actively discouraged, since these are practices that are tied to people's identity. However, improved promotion of and access to interventions for both indoor and outdoor transmission will help to reduce the risk of malaria transmission and complement existing indoor interventions for malaria prevention and control.