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High entomological inoculation rate of malaria vectors in area of high coverage of interventions in southwest Ethiopia: Implication for residual malaria transmission

Misrak Abraham[a], Fekadu Massebo[a,*], Bernt Lindtjørn[b]

[a] Department of Biology, Arba Minch University, Arba Minch, Ethiopia
[b] Centre for International Health, University of Bergen, Bergen, Norway

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ABSTRACT

In Ethiopia, vector control is the principal strategy to reduce the burden of malaria. The entomological indicators of malaria transmission such as density, sporozoite rate and entomological inoculation rate (EIR) are parameters used to assess the impact of the interventions and the intensity of malaria transmission. The susceptibility of malaria vectors also determines the effectiveness of insecticide based vector control tools. Hence, the aim of the study was to assess the species composition, sporozoite rate and EIR, and insecticide susceptibility status of malaria vectors.

33 houses (18 for Centre for Disease Control and Prevention (CDC) light traps and 15 for exit traps) were randomly selected to sample *Anopheles* mosquitoes from October 2015 to May 2016. *Plasmodium* circum-sporozoite proteins (CSPs) of *An. arabiensis* and *An. pharoensis* were determined using Enzyme-Linked Immuno-Sorbent Assay (ELISA).

Five *Anopheles* species were identified from CDC Light traps and exit traps. *An. arabiensis* (80.2%) was the predominant species, followed by *An. pharoensis* (18.5%). *An. pretoriensis*, *An. tenebrosus* and *An. rhodesiensis* were documented in small numbers. 1056 *Anopheles* mosquitoes were tested for CSPs. Of which nine (eight *An. arabiensis* and one *An. pharoensis*) were positive for CSPs with an overall CSP rate of 0.85% (95% CI: 0.3–1.4). Five *Anopheles* mosquitoes were positive for *P. falciparum* and four were positive for *P.vivax*_210. *P. falciparum* CSP rate of *An. arabiensis* was 0.46% (95% CI: 0.13–1.2) and it was 0.54% (95% CI: 0.01–2.9) for *An. pharoensis*. The overall EIR of *An. arabiensis* was 5.3 infectious bites per/person (ib/p)/eight months. *An. arabiensis* was resistant to dieldrin (mortality rate of 57%) and deltamethrin with mortality rates of 71% but was fully susceptible to propoxur and bendiocarb. Based on the EIR of *An. arabiensis*, indoor malaria transmission was high regardless of high coverage of indoor-based interventions.

Finally, there was an indoor residual malaria transmission in a village of high coverage of bed nets and where the principal malaria vector is susceptibility to propoxur and bendiocarb; insecticides currently in use for indoor residual spraying. The continuing indoor transmission of malaria in such village implies the need for new tools to supplement the existing interventions and to reduce indoor malaria transmission.

* Corresponding author.
E-mail addresses: fekadu.massebo@amu.edu.et (F. Massebo), bernt.lindtjorn@cih.uib.no (B. Lindtjørn).

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1. Introduction

Malaria is a severe disease resulting deaths, sickness and economic losses in tropics and subtropics (Gething et al., 2016; Murray et al., 2012). Until the mid-19th century, malaria was endemic in most countries in the world (Mendis et al., 2009). In 1955, a global malaria eradication campaign was launched to interrupt transmission using Dichloro-Diphenyl-Trichloroethane (DDT) (Najera et al., 2011). As a result of the campaign, several countries that were endemic in 1950s' were free from malaria by 1970s' (Najera et al., 2011). Currently, malaria has been declined in most malaria endemic countries due to the widespread distribution of public health interventions (Bhatt et al., 2015). Despite all efforts, it remains as a major public health problem of the world with annual estimate of 212 million cases and 429,000 deaths in 2015. About 92% of deaths occurred sub-Saharan Africa alone (WHO, 2016a).

In the last 10 years, malaria control efforts have been scaled up across Africa. Indoor residual spraying (IRS) and long lasting insecticidal nets (LLINs) are the two major interventions contributing for the current malaria reduction (Bhatt et al., 2015). These malaria control interventions have averted 663 million cases since 2000 of which 68% of cases were by long-lasting insecticidal nets (LLINs), 22% by artemisinin based combination therapy (ACT) and 10% by indoor residual spray (IRS) (Bhatt et al., 2015). But the control of malaria is being threatened by insecticide resistant malaria vectors (Ranson and Lissenden, 2016). Also, limited numbers of public-health insecticides are available for vector control (Hemingway et al., 2013). For example, pyrethroid insecticide are the only insecticides for treating bed nets, and only four classes of insecticides are available for IRS. Moreover, malaria vectors are rapidly developing resistance to all insecticides for public use (Ranson and Lissenden, 2016). Hence, implementation of effective insecticide resistance management strategies is vital to mitigate the development and spread of insecticide resistance.

Moreover, the entomological indicators such as density, species composition, sporozoite rate and entomologic inoculation rate (EIR) are important parameters to measure the impact of vector control interventions. EIR in particular is crucial to quantify the exposure of the human population to malaria vectors (Shaukat et al., 2010). Little information is available on EIR of the principal malaria vector *An. arabiensis* in Ethiopia (Animut et al., 2013; Massebo et al., 2013a). The *Plasmodium falciparum* sporozoite rate of 0.5% for *An. arabiensis* from human landing catches (HLC) was documented in Sille in 2006 (Taye et al., 2006). *An. arabiensis* was dominant species, and *An. coustani* was the second dominant species in the village (Taye et al., 2006). The village is still malaria endemic regardless of the implementation of massive vector control interventions such as IRS and LLINs. Hence, the current information on the species composition, vector density, sporozoite rate of *Anopheles* mosquitoes, and EIR and insecticide susceptibility status of *An. arabiensis* are relevant for evaluating the impact of existing vector control interventions and planning for appropriate supplementary interventions. Hence, the aims of the study were to investigate the species composition, sporozoite rate and EIR of *Anopheles* mosquitoes, and assess the susceptibility status of *An. arabiensis* in Sille village ten years after the previous survey in the same area.

2. Materials and methods

2.1. Description of the study area

The study was conducted in Sille (5°99′ N and 37°50′ E), one of malaria endemic villages of Gamo Gofa zone, southwest Ethiopia (Fig. 1). It is located 518 km from Addis Ababa, capital of Ethiopia, 308 km from Hawassa, capital of South Nations Nationalities and Peoples Regional State (SNNPRs) and 13 km from Arba Minch, capital of Gamo Gofa zone. The altitude ranges from 1120 to 1380 m above sea level. Its temperature range from 25 to 36 °C and mean annual rainfall ranges from 900 to 1300 mm (millimeter). The village has high potential of irrigation. The water sources for irrigation are Sille River and Lake Chamo. The primary economic source is agriculture, and banana is the main cash crop.

There is large number of animals in the village. During the night, animals kept either in separate animal houses (just to protect from rain), outdoors in the compound or in communal places. Hence, humans and animals do not share the same house. No seasonal or permanent movement of animals (live permanently in the village). Corrugated roofed and grass thatched houses are found in the village. The total human population of the village is 3452. There is one health post in the village to provide basic public health services mainly focusing on prevention. IRS and LLINs are the two major vector control interventions implemented by the District Health Office. IRS of either propoxur or bendiocarb conducted once a year. 88% (3048/3452) of the total population was protected by IRS in 2016, while LLINs distribution was based on the number of household occupants. Those households with 1–2 occupants had 1 bed net; those with 3–4 had 2 bed nets, 5–7 had 3 bed nets and ≥ 8 had 4 bed nets. The bed nets coverage was > 98% (Arba Minch area district health office unpublished data, 2016).

2.2. Adult Anopheles mosquito sampling by Centre for Disease Control and Prevention (CDC) light trap

Adult female *Anopheles* mosquito sampling was carried out in Sille village from October 2015 to May 2016 using CDC light traps (Model 512; John W. Hock Company, Gainesville, FL, USA). Sample collection was carried out three times each month in 18 randomly selected houses. CDC light traps were installed 45 cm above the floor at the foot end of a human sleeping under untreated mosquito nets in house (Lines et al., 1991). Traps were switched on at 18:00 PM and switch off at 6:00 AM. All mosquitoes collected in the traps were removed from the bags, counted, identified morphologically into species using a key (Gillies and Coetzee, 1987). Live female *Anopheles* mosquitoes were killed either by freezing or by suffocation with chloroform vapor. Abdominal conditions of female were examined under a dissecting microscope and classified into unfed, freshly fed, half-gravid or gravid (WHO, 2003). The female *Anopheles* mosquitoes were preserved individually in vials with silica gel for circum-sporozoite proteins (CSPs) analysis. The