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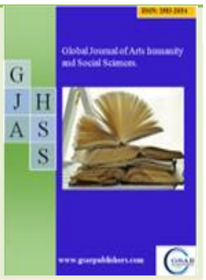

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FACTORS ASSOCIATED WITH RESIDUAL MALARIA TRANSMISSION IN GOKWE SOUTH DISTRICT, MIDLANDS PROVINCE, ZIMBABWE, 2023

BY

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Abstract

The incidence of malaria in Gokwe district remains high despite numerous interventions such as the indoor residual spraying (IRS) and health education. This has resulted in numerous mortalities and morbidities among the residents of Gokwe District. A cross sectional study was carried out in Gokwe District to determine the factors associated with residual malaria transmission in Gokwe District. Mosquito samples were collected overnight to determine the biting times. A questionnaire was used to collect data on the sleeping patterns of the residents of Gokwe South district. Two wards (11 and 12) were involved in the study and a total of 84 participants. Analysis was carried out using Epi info version 7. Data was analysed for descriptive statistic for means and proportions. Odds ratios were calculated to determine the association of the variable with risk of contracting malaria. Logistic regression was used to determine the independent factors associated with contracting malaria in Gokwe South District. Most of the participants were female 47(56 .0%) and males were 37(44 .0%), Level of education and 38(45 .2%) had attained secondary education. Most, 45 (53 .6%) of the participants were involved in farming. All the mosquitoes identified were the *Anopheles gambiae sensu lato (s.l).* Of all the participants, 41.7 indicated that the mosquitoes that bite them also bites cattle, while, 27.4 said they prefer to bite humans and 27.4 said they prefer to bite poultry, while only 3.6 % said they prefer to bite goats. The peak collection time outdoors for the An. gambiae sensu lato species was at 8-9 pm as well as at 4-5 am. The peak biting times as indicated by the participants was night time. The major drivers of residual malaria in Gokwe District were established as: resting/relaxing outdoors at night (aOR: 11.5; CI: 3.3-40.2), at times sleeping outdoors (aOR: 5.4; CI: 1.7-17.7) and bathing outdoors before sleep (aOR: 5.1; CI: 1.1-22.7). It is concluded that the major drivers of residual malaria in Gokwe South District were resting/relaxing outdoors at night, sleeping outdoors and bathing outdoors before sleep. It is recommended that residents of Gokwe district should not relax or sleep out doors at night or should wear mosquito repellent.

Keywords: Gokwe South, Malaria, Residual, Transmission, Mosquito

Introduction

The incidence of malaria in Gokwe district remains high despite numerous interventions such as the indoor residual spraying (IRS) and health education. This has resulted in numerous mortalities and morbidities among the residents of Gokwe District. A cross sectional study was carried out in Gokwe District to determine the factors associated with residual malaria transmission in Gokwe District.

Mosquito samples were collected overnight to determine the biting times. A questionnaire was used to collect data on the sleeping patterns of the residents of Gokwe South district. Two wards (11 and 12) were involved in the study and a

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Most of the participants were female 47(56 .0%) and males were 37(44 .0%), Level of education and 38(45 .2%) had attained secondary education. Most, 45 (53 .6%) of the participants were involved in farming. All the mosquitoes identified were the *Anopheles gambiae sensu lato (s.l).* Of all the participants, 41.7 indicated that the mosquitoes that bite them also bites cattle, while, 27.4 said they prefer to bite humans and 27.4 said they prefer to bite poultry, while only 3.6 % said they prefer to bite goats. The peak collection time outdoors for the An. gambiae sensu lato species was at 8-9 pm as well as at 4-5 am. The peak biting times as indicated by the participants was night time. The major drivers of residual malaria in Gokwe District were established as: resting/relaxing outdoors at night (aOR: 11.5; CI: 3.3-40.2), at times sleeping outdoors (aOR: 5.4; CI: 1.7-17.7) and bathing outdoors before sleep (aOR: 5.1; CI: 1.1-22.7). It is concluded that the major drivers of residual malaria in Gokwe South District were resting/relaxing outdoors at night, sleeping outdoors and bathing outdoors before sleep. It is recommended that residents of Gokwe district should not relax or sleep out doors at night or should wear mosquito repellent.

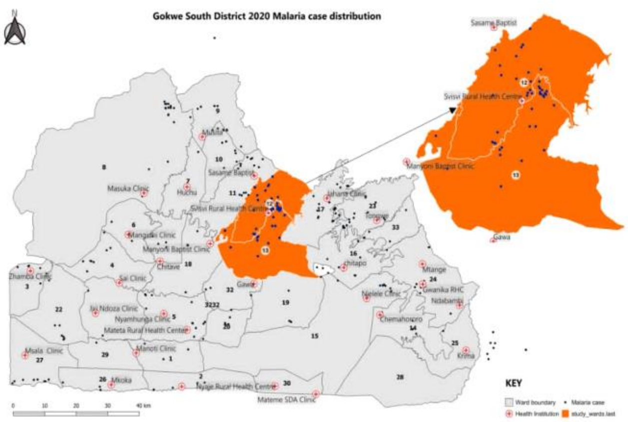

Figure 3.1 Study site

The study was done in Gokwe South District, Midlands Province and two rural wards (12 and 13) of the district constitute the study population. All the households in the 2 selected rural wards of Gokwe South district constituted the study sites.

Study population and sample size calculation

The study site consisted of 5048 households derived from the two wards. All the inhabitants of these household constituted the study population from which the sample was drawn. The households per sentinel were: ward 12 (2716) and ward 13(2332). Using sample size calculator, 84 households were selected out of the 5048 households at 95% confidence, 0.05 margin of error and 0.05 sample proportion.

Formular: $n = N * \frac{Z^2 * P * (1-p)}{e^2} \Big/ [N-1+\frac{Z^2 * p * (1-p)}{e^2}]$

The sample households per each sentinel site were chosen proportionally. The sample households per sentinel were: ward 12 (43) and ward 13(41). From each household, one participant was selected randomly into the study.

Sampling procedure

The two wards were wards 12 and 13. Households were included basing on proportional representation and systematically sampled. Households in the two wards were separately allocated numbers and the researcher took 41 households in ward 12 which has a total of 2716 households where every 60^{th} household was selected to reach a total of the selected 43. For ward 13 which had a total of 2332 household, every 55^{th} household was selected to come up with the required 41 households in that ward. A Kish Grid method was used to select the interviewees within those households.

Data collection procedure

Morphological identification of female anopheles mosquitoes was done using identification keys developed by Gilles and Coetzee (1987) as well as on morphological characteristics using published keys according to the nomenclature of Wilkerson et al(Wilkerson et al., 2015). Catchers were trained to collect landing mosquitoes through CDC light traps for both indoor and outdoor collection during dusk, night and dawn to determine indoor and outdoor biting preferences. Indoor and outdoor human biting Anopheles mosquitoes were collected every hour from 17:00 to 07:00 hours to determine biting times for both outdoor and indoor biting. The Kish grid was used to select members within a household to be interviewed. The Kish grid uses a pre-assigned table of random numbers to find a person to be interviewed on sleeping patterns within the selected household. Only members of the households who are 18 years and above were included for participation. A questionnaire was administered to participants to determine the mosquito biting times and to corroborate the results of the CDC trap findings on the biting times. The questionnaire, also captured information on the malaria status i.e whether the participant suffered from malaria or not. Furthermore, the sleeping patterns in relation to socioeconomic factors associated with contracting malaria were collected using the questionnaire.

Ethical Considerations

Permission was sought from the Provincial Medical Director and the District medical Director for Midlands provinces and Gokwe South District respectively. Written informed consent before participating in the study was sought from all participants. All matters of confidentiality were included in the informed consent forms which were completed by all the study participants. To personal identity data was sought captured or sought.

Inclusion criteria and exclusion criteria

All households with adults who were 18 years and above were included in the study while all households found locked during data collection were excluded. The selected participant was supposed to be a resident in the selected village. The study excluded children who were under the age of 18 for ethical reasons and furthermore most of them were not heads of the household. Both, those who suffered from malaria in 2021 and those who did not suffer from malaria were eligible to participate in the study. Visitors, non-consenting participants and people who were very sick were not be included in the study.

Data collection instruments

CDC light traps were used to collect mosquitoes for both outdoors and indoors. A structured closed-ended questionnaire was be used for collecting data. The questionnaire was prepared in English and was translated to Shona, the language that most of the residents in the area understands. The questionnaire included questions about the respondent's socio-demographic characteristics, sleeping patterns for both outdoor and indoor, household chores for both dawn and dusk times, LLINs use and their socio-economic activities during the various risk hour of the day.

Research participants

Total number of human participants enrolled for questionnaire on sleeping patterns were derived from 84 households selected for CDC light catches and the participants were residents of those selected 84 households in wards 12 and 13 in Gokwe South district.

Source of recruitment/ study site

The study site included households in Gokwe South District's wards 12 and 13.

Age range and sex

The study included people who were 18 years and above. Both males and females were included in the study.

Special/ Vulnerable population

The study included pregnant women if they were selected in the Kish grid selection at household level.

Informed Consent

After being authorized to conduct the study in the district by the District Medical Officer, the researcher further sought authority to conduct the study from the village heads of the selected villages. The researcher then visited the selected households sought permission from the head of the household and then the participant. Participants were interviewed basing on the questions written on the pretested questionnaire while at the same time asking for permission to set CDC light traps at the same households where questionnaires were administered. Consent to enter the house and to set the traps was sought both from the head of the household and the occupants would only enter the house after being given the permission.

Confidentiality/privacy

The information obtained from the study was only accessed by the investigator and records were kept confidential and all data was coded to represent household names. The collected data was used strictly for the purpose of this study and was pass-word protected. Participants were given an individual identification number, so there was no personal identifiable information attached to the data.

Data analysis and presentation

Quantitative data was analyzed using Epi-info 7. Descriptive variables were presented using frequencies and proportions. Bivariate analysis was carried out to determine the odds ratios (ORs) for contracting malaria, while multiple logistic regression analysis was used to determine independent factors associated with residual malaria. For the bivariate analysis and multiple logistic regression analysis, the outcome variable was: having suffered from malaria and thus a case was defined as a participant selected into the study who contracted malaria in Gokwe South District in in the year 2023, while a control was a respondent who did not contract malaria in the same period. Data was presented in the form of tables and graphs.

RESULTS

Demographic characteristics of participants, Gokwe South district

Females constituted 56% (47), while males constituted 44 % (37) of all the participants (Table 4.1, below). On level of education, 45.2 % (38) had reached secondary school, 40.5 % (38) had attained primary education, while 2.4 % (2) had reached tertiary education while 11.9% (10) had no education at all. In terms of employment, 10.7 % (9) were involved in buying and selling, 53.6 % (45) were involved in farming, one was involved in mining, 8.3% (7) were involved in peddling while 26.2 (22) were unemployed.

Table 4.1: Demographic characteristics of participants, Gokwe South

Characteristic	Variable	Frequency(n)	Percentage (%)
Sex	Female	47	56 .0
	Male	37	44 .0
Level of education	None	10	11 .9
	Primary	34	40 .5
	Secondary	38	45 .2
	Tertiary	2	2 .4
Employment	Buying and selling	9	10 .7
	Farming	45	53 .6
	Mining	1	1 .2
	Peddling	7	8 .3

Unemployed	22	26 .2

Morphological identification of female Anopheles mosquitoes

The mosquitoes were identified morphologically. All the mosquitoes identified were *the Anopheles gambiae sensu lato (s.l)* species and the example of *Anopheles gambiae sensu lato*(Figure 4.1,below).

Figure 4.2 : Anopheles mosquito caught in Gokwe south district: *An. gambiae s.l*

Preference of host feeding habits

Most of the mosquitoes captured were unfed due to the fact that most of the mosquitoes were captured before their blood meal. However, the pie chart below shows some of the feeding preferences that the community members indicated for the mosquitoes that usually attack them. Of all the participants, 41.7 indicated that the mosquitoes that bite them also bites cattle, while, 27.4 said they prefer to bite humans and 27.4 said they prefer to bite poultry, while only 3.6 % said they prefer to bite goats.

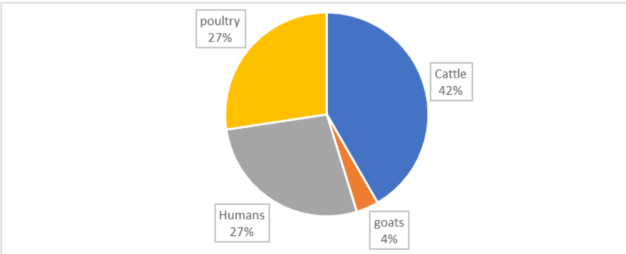

Figure 4.3: Mosquito feeding preferences as suggested by participants

Biting preferences of the female mosquitoes as to whether indoor/ outdoor biting against each period of collection.

The peak collection time outdoors for the *An. gambiae sensu lato* species was at 8-9 pm as well as at 4-5 am (Fig 4.1, below). From 5 to 7 pm there were no Anopheles mosquitoes caught both indoors and outdoors, as well from 12-2 am. The peak collection times for indoor was 9 to 10 pm, followed by 7 to 8 pm. There were no mosquitoes that were caught indoors between 11pm to 2 am.

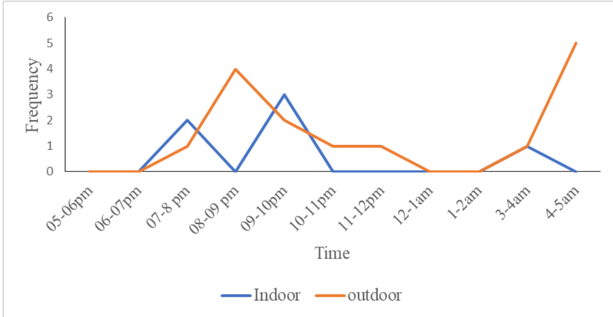

Figure 4.4 : Indoor/outdoor biting preferences of *Anopheles gambiae sensu lato*, Gokwe south District

Biting times of the female Anopheles mosquitoes in the selected 2 wards of Gokwe district.

The biting times of the mosquitoes as indicated by the participants were found to be: night time 42.86% (36), followed by dusk at 39.3% (33) while the lowest number (3.6%) of mosquito bites were experienced during daytime *(Figure 4.2, below)*. Some bites were experienced early morning as indicated by 14.3% of the participants. Night time represented the largest number of mosquito bites experienced by the participants.

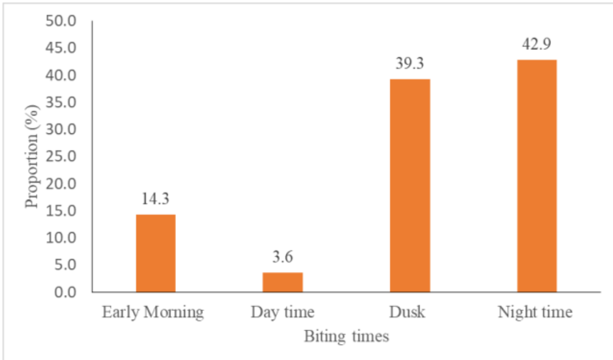

Figure 4.5 Biting times of the female Anopheles mosquitoes in 2 selected wards of Gokwe south district

Human sleeping patterns in relation to social and economic activities and the risk of contracting malaria in Gokwe South District

The human sleeping patterns in relation to socio-economic activities are documented in table 4.4, below. Those who relaxed outdoors before sleep were more likely to contract malaria (OR 6.4; CI: 2.3-18.3) than those who did not, while those who bathed outside before sleep where 5.16 times more likely to contract malaria (OR:5.2; CI: 1.5-17.9), than those who did not. The odd of contracting malaria were higher among those who woke up in the morning to do some activity such as farming or going to work (OR 4.5; CI: 1.5-13.7) than those who did not while those who's sometimes slept outdoors (OR: 2.1; CI: 1.2-8.5), were 2.1 times more likely to develop malaria than those who do not. Farming late into the night (OR: 3.5; CI: 1.1-11.5) and going to church (OR: 2.3; CI: 0.9-5.9) were statistically significant risk factors for contracting malaria, while visiting a beer hall before sleep was not a statistically significant risk factor (OR: 2.6; CI: 1.1-6.6).

Table 4.4: Human sleeping patterns, social and economic activities as risk factors for contracting malaria in Gokwe South District

Factor		Case n=35(%)	Control n=49(%)	Total n=84(%)	OR	95C.I	p-value
Rests /Relaxes outdoors before sleep	Yes	29(82 .9)	21(42 .9)	50(59 .5)	6 .4	2 .3 -18 .3	<0 .010
	No	6(17 .1)	28(57 .1)	34(40 .5)			
Baths outdoors before sleep	Yes	11(31 .4)	4(8 .2)	15(17 .9)	5 .2	1 .5 -17 .9	<0 .010
	No	24(68 .6)	45(91 .8)	69(82 .1)			
Wakes up early to do some activity	Yes	30(85 .7)	28(57 .1)	58(69 .0)	4 .5	1 .5 -13 .6	<0 .010
	No	5(14 .2)	21(42 .9)	26(31 .0)			
Farming late into the night before sleep	Yes	10(28 .6)	5(10 .2)	14(16 .7)	3 .5	1 .0 -11 .5	0 .031
	No	25(71 .4)	44(89 .8)	70(83 .3)			
Going to church before sleep/ for an all night	Yes	17(48 .6)	13(26 .5)	29(34 .5)	2 .6	1 .1 -6 .6	0 .040
	No	18(51 .4)	36(73 .5)	55(65 .5)			
Sometimes sleeps out doors	Yes	27 (77 .1)	25(51 .0)	52(61 .9)	2 .1	1 .23 -8 .53	0 .010
	No	8 (22 .9)	24(49 .0)	32(38 .1)			
Visits the beer hall before sleep	Yes	10 (28 .6)	12(24 .5)	22(26 .2)	1 .2	0 .5 - 3 .3	0 .341
	No	25 (71 .4)	37(75 .5)	37(73 .8)			

Independent Factors Associated with Residual Malaria in Gokwe South District

Multiple logistic regression analysis was carried out to determine the key drivers of residual malaria in Gokwe South District. These are tabulated in table 4.5 below. The major drivers of residual malaria in Gokwe District were established as: resting/relaxing outdoors at night (aOR: 11.5; CI: 3.3-40.2), at times sleeping outdoors (aOR: 5.4; CI: 1.7-17.7) and bathing outdoors before sleep (aOR: 5.1; CI: 1.1-22.7).

Table 4.5 Independent Factors Associated with Residual Malaria in Gokwe South District

Independent factor	aOR	95% C. I	P-Value
Resting/relaxing outdoors at night	11 .5	3 .3-40 .2	<0 .010
Sometimes sleeping outdoors	5 .4	1 .7-17 .7	<0 .010
Bathing outdoors before sleep	5 .1	1 .1-22 .7	0 .030

*aOR: adjusted odds ratio

Discussion

Most of the mosquitoes caught were the *Anopheles gambiae sensu lato(s.l.)* species. In Africa, the prominent malaria vector species include *An. Gambiae s.l species* (Maliti et al., 2016). The major anopheline malaria vectors across sub-Saharan Africa are *Anopheles funestus s.s.* and *Anopheles gambiae s.l* complex (Erlank et al., 2018). *An. gambiae s.l* is naturally endophilic (Pates & Curtis, 2005) most efficient anthropophilic vector species (Hamon, 1963). Most of the An. gambie species were picked outside the homesteads. *Anopheles gambiae s.l.* complex, mosquitoes are responsible for the transmission of malaria in the country(Mpofu, 1985). Presence of *An. arabiensis* mosquitoes was reported in the urban towns of Kwekwe, Chirundu, Kariba and Binga(H Masendu et al., 2005). In this study *An. arabiensis* was not found in Gokwe south district. No *An. funestus* were picked in this study but were reported mosquitoes in Honde Valley (Choi et al., 2014). This may show the geographical limitation of *An. arabiensis* and *An. funestus.*

The resistance of *An. gambiae* mosquitoes to DDT in Gokwe has also been attributed to the high usage of organochlorines by villagers, as well as a long history of DDT usage in this area for agricultural (especially cotton farming) and public health purposes, mainly tsetse and mosquito control (Munhenga et al., 2008). Thus, this may explain the continued presence of *An. gambiae s.l.* and thus being the major driver of sustained malaria incidence in Gokwe south district.

The anopheles' mosquitoes were said to feed on humans and cattle and poultry. This agrees with other researches elsewhere (Clements, 1992; Chaves et al., 2010). Most mosquito species were found to share at least one host species (Chaves et al., 2010). Many mosquito species are anthropophilic, including the *An. Gambiae s.l* with respect to host preference and play an important role in the global transmission of the pathogens responsible for diseases such as malaria (Bashar et al., 2015).

The propensity of malaria vectors such as *An. Gambiae s.l.* to feed on humans rather than nonhuman hosts has important epidemiological consequences for malaria transmission (Zimmerman et al., 2006). The pattern of feeding is influenced by several factors, including the intrinsic host preference of the species, nutritional requirements, host availability, vector density, and social and cultural practices of the human population (Loyola et al., 1993).The human-biting habits and mean longevity are the most important epidemiological factors in malaria transmission by anopheles that can transmit human malaria parasites (Zimmerman et al., 2006).

Anopheles gambiae s.l. , is the major malaria vector that has been suggested to be highly anthropophilic (Killeen et al., 2001) and does have a strong preference for humans even when given other choices of blood hosts under controlled field settings. Elsewhere such as in areas of Burkina Faso *Anopheles gambiae*, uses cows as its primary blood source, because of the widespread use of bed nets, humans are not available as blood source (Lefèvre et al., 2009). These findings are consistent with the findings of this current study in that the participants reported that the mosquitoes feed on other animals such as cattle and poultry. The blood meal test could not yield any positive result. This could be because the mosquitoes were not yet fed after the catches. This is because the CDC light traps usually catch unfed mosquitoes. Most of the mosquitoes were caught outdoors than indoors. A similar study elsewhere showed that the outdoor point had higher abundance than the indoor one (Ombugadu et al., 2020). Adult men and women were elsewhere reported to be awake before 6 am suggesting additional potential exposure in the early morning (Rodríguez-Rodríguez et al., 2021). Outdoor exposure in the early hours of the evening and in some settings early in the morning, highlight the need for complementary interventions offering outdoor protection (Thomsen et al., 2017). The considerable amount of time spent outdoors presents a window of potential exposure to malaria-carrying mosquitoes because LLINs primarily prevent indoor biting (Rodríguez-Rodríguez et al., 2021).

In this study the maximum activity of *An. Gambiae s.l* was recorded during the 8-9pm. *An. Gambiae (s.l.)* is highly endophagic (preference to feed indoors) and anthropophagic (preference for biting humans) (Maliti et al., 2016) and feeds predominantly between 9 pm–3 am (Maxwell et al., 1998). Feeding site may be exophagic and/or endophagic, depending on local circumstances (e.g., vegetation cover, type of house) and host availability (Abonuusum et al., 2011).

The fact that most of the mosquitoes were caught outdoors indicates that *An. gambie* has got some exophagic potential. This is further confirmed by the fact that some of the participants indicated that they were bitten by mosquitoes outdoors due to the anthropophilic nature of the mosquitoes (Moreno et al., 2017). Anopheles mosquitoes that bite or rest outdoors are not readily tackled by LLINs or IRS, and therefore can perpetuate residual disease transmission (Thomsen et al., 2017). This, together with poor LLINs usage explains the continued high incidence of malaria in Gokwe south district. Historically, human malaria infections in sub-Saharan Africa occur mainly during late hours of the night (Milali et al., 2017). In this study *An. gambiae s.l* was picked during the early hours of the night (8-9 pm) and early hours of the morning (4-5am). This period coincides with the peak biting behaviour of the primary malaria vector: *Anopheles gambiae sensu lato* (Milali et al., 2017).

Participants showed a huge activity in the early morning and early evening. This study also established that the participants were being bitten by mosquitoes outdoors. Within the *An. gambiae (s.l.)* there have been reports of shifts in their behaviours such as increased tendency to feed outdoors (Thomsen et al., 2017). This is corroborated by other studies elsewhere including in countries such as Tanzania (Gryseels et al., 2015). Early evening and morning outdoor exposure of humans to mosquito bites has epidemiological importance in terms of controlling transmission in this setting, and possibly across sub-Saharan Africa and beyond (Moiroux et al., 2012) where ITNs and/or indoor residual spraying (IRS) remain the only interventions (Milali et al., 2017). Most of the participants in this study were bitten by mosquitoes whilst having some outdoor activities. Documenting human activity at night is crucial to understanding human-vector interaction and its effect on malaria control (Monroe et al., 2015). *Matowo et al.* in southern Tanzania, described evening, night-time and early morning activities comparable to those observed in this study and described *An. Funestus* biting patterns (Matowo et al., 2013).To curtail residual malaria transmission, it is essential to identify malaria prevention strategies compatible with human behaviour (Monroe et al., 2015) social, cultural and livelihood activities on malaria control (Alaii et al., 2003). Outdoor activities may expose people to mosquito bites (Choi et al., 2014), even under conditions of full coverage, IRS and ITNs provide minimal protection when people are both outdoors and active during anopheles biting periods. In a study carried out in Ghana most of the entire population was outdoors and active during the early evening when biting began (Monroe et al., 2015). Studies done elsewhere in Ghana show that significant transmission can occur during the early evening hours (Abonuusum et al., 2011).

Most of the participants were active during the early hours of the morning. While biting rates are lowest during this time, a large percentage of the population is at risk (Monroe et al., 2015). Most of the participants indicated that they would be outdoors during the night. Some common large-scale events, such as funerals last the entire night (Monroe et al., 2015). The persistence of malaria in Gokwe south district could be due to the fact that ITNs and IRS primarily address endophagic (indoor-feeding) and endophilic (indoor- resting) vectors. The presence of exophagic (outdoor-feeding) and exophilic (outdoor-resting) mosquitoes may limit their effectiveness (Monroe, 2015), resulting in residual malaria despite interventions being in place in Gokwe South district.

In this study most of the participants had some numerous outdoor activities in the evening and at night. The most common reason for staying awake was found to be at church, having some all-night and being at beer halls. Other studies done elsewhere indicated that the most frequent motive for staying awake was funeral attendance (Monroe et al., 2015) , doing chores, eating dinner and socializing within the compound (Monroe et al., 2015). In this study the key drivers for the residual malaria were established as: sleeping outdoors, bathing outdoor before sleep and resting and relaxing outdoors. These outdoor activities could explain the persistence of the high malaria cases in Gokwe south district. Elsewhere studies have indicated similar findings (Milali et al., 2017; Monroe, 2015). The major reasons given in this study for staying out doors, resting/ relaxing, were that it would be too hot indoors and the need to attend some social functions. Due to the changing malaria epidemiology, outdoor transmission is becoming an important focus for malaria control strategies today (Gryseels et al., 2015).

Social patterns and human behavior may determine exposure to Anopheles mosquitoes and have an effect on transmission (Rodríguez-Rodríguez et al., 2021). Early evening was also an important time for socializing among family, friends and neighbors (Monroe et al., 2015). The findings of this study are in agreement those of others such as in India (Pandian & Chandrashekaran, 1980) in which socializing during the times of pick mosquito activity was responsible for residual transmission.

Most of the participants could not sleep under mosquito nets. While the potential of LLINs to reduce malaria morbidity is well known (Pryce et al., 2018) , inconsistent or low use limits their effectiveness and may lead to differential impact of this intervention in different sites (Rodriguez-Rodriguez et al., 2019) .

More recently, it has been reported that a substantial change in species composition of malaria vectors (Bayoh et al., 2010) and a shift in biting time (Azizi et al., 2011) is associated with the widespread use of ITNs across Africa (Milali et al., 2017). Elsewhere, consistent with the findings of this study, non-usage of ITNs was one of the major factors associated with an increased risk of malaria infection (Fana et al., 2015). Failure to use ITNs is associated with malaria prevalence and parasite density, and those who do not use ITNs regularly have a high occurrence of malaria infection with a high parasite density, as compared to those who use ITNs on a daily basis (Fana et al., 2015). Inconsistent use or use for only a fraction of the hours when malaria transmission occurs limits their effectiveness (Monroe et al., 2015).

Most the participants in this study indicated that they would wake up in the morning. Early evening and morning outdoor exposure of humans to mosquito bites has epidemiological importance in terms of controlling transmission in this setting, and possibly across sub-Saharan Africa and beyond (Moiroux et al., 2012) where ITNs and/or indoor residual spraying (IRS) remain the only interventions (Milali et al., 2017). High community compliance in ITN use, timely case diagnosis and treatment, and maintenance of the existing surveillance and response system will be critical to the goal of achieving and sustaining malaria elimination in the future (Chan et al., 2021).

Conclusion

It can be concluded that the most common mosquito species in Gokwe South is *An. Gambie sensu lato*. This mosquito is most incriminated in the spread of malaria. The mosquitoes are most active during the early hours of the night and the early hours of the morning. The increase in the number of people affected with malaria in Gokwe south district could be due to the socioeconomic activities they perform during the early hour of the night as well as during the early hours of the morning. Thus, sleeping patterns, as affected by socioeconomic activities could be causing sustenance of high malaria incidence in Gokwe south district. Controlling malaria with LLINs and IRS has certain fundamental limitations in regions such as Gokwe South district, characterized by early and outdoor biting, thus improving coverage of LLINs alone might not achieve malaria elimination. The peak biting activity by *An. Gambiae s.l* coincides with the times most people would be outside and not able use bed nets, calls for optimization of vector control and behavioural change strategies. Overall, malaria control measures are failing to effectively control and eliminate malaria in Gokwe South district due to the biting behaviour of the *An. gambie s.l.* coupled by the human behaviour related to the sleeping patterns which act as the major drivers of residual malaria in the district.

It is recommended that a number of interventions, implemented together, aiming for personal protection during evening and night activities are essential and should be implemented in Gokwe south district to reduce the continued occurrence of malaria in the district. Novel tools in malaria and mosquito control should be incorporated into the Integrated Vector Management system in Gokwe South district. There is need for an increase in the number of mosquito nets, to cater for outdoor use as well, for the control of mosquito bites in Gokwe south district coupled with behaviour change and communication. Thus, further education of the community members in Gokwe district has to be implemented. During the night the, residents of Gokwe should be advised to put on long covering clothes and use mosquito nets when sleeping outdoors at night. Furthermore, they should be advised to bath indoors when it is dark or to bath before it becomes dark. These interventions will help curtail the spread of malaria Gokwe South district by addressing the key drivers of residual malaria in the district. Regular education and training of community health workers in the education and training of the community members on prevention and control of mosquitoes and malaria should be done.

Promoting outdoor LLINs use may help, but community-based participatory research will be essential to assess feasibility and acceptability. Complementary methods to LLINs are needed to prevent outdoor biting in the evenings and the morning. New interventions should focus on disrupting malaria transmission beyond bedtime hours, specifically before and immediately after bedtime. Interventions such as insecticide-treated clothing, topical and spatial repellents are recommended.

From an epidemiological standpoint, it is crucial to be able to accurately identify mosquito blood-meals for studies of transmission dynamics of parasitic pathogens such as malaria. Further research is needed using other methods, such as pyrethrum spray catches, to determine the Human Blood Index (HBI), formerly known as the anthropophilic index or human blood ratio which determines the proportion of blood that has been taken from a human being, is recommended. This index will help in the determination of the vectoral capacity of *An. gambiae s.l.* in Gokwe district and allow a more focused control of this malaria vector.

Spatial repellents in Gokwe south district, designed to shield a space rather than an individual, could be useful at large-scale outdoor events by protecting a group of people without requiring individual application. Furthermore, these spatial repellents may be useful as well for use when on the fields as well as when they are at church.

REFERENCES

1. Abonuusum, A., Owusu-Daako, K., Tannich, E., May, J., Garms, R., & Kruppa, T. (2011). Malaria transmission in two rural communities in the forest zone of Ghana. *Parasitology Research*, *108*, 1465–71.
2. Alaii, J., Hawley, W., Kolczak, M., ter Kuile, F., Gimnig, J., & Vulule, J. (2003). Factors affecting use of permethrin-treated bed nets during a randomized controlled trial in western Kenya. *American Journal of Physiology J Trop Med Hyg.*, *68*, 137–41.
3. Atulomah, B. C., & Atulomah, N. O. (2012). Health literacy, perceived-information needs and preventive-health practices among individuals in a rural community of Ikenne Local Government Area, Nigeria. *Ozean J. Soc. Sci.*, *5*(3), 95–104.
4. Azizi, S., Drakeley, C., Kachur, S., & Killeen, G. (2011). Russell TL, Govella NJ, Increased proportions of outdoor feeding among residual malaria vector populations following increased use of insecticide-treated nets in rural Tanzania. *Malaria Journal*, *10*, 80.
5. Baird, J. (2005). Effectiveness of antimalarial drugs. *N Engl J Med*, *352*, 1565–1577.
6. Bannor, R., Asare, A. K., Sackey, S. O., Osei-, R., Nortey, P. A., Bawole, J. N., Ansah, V., Bannor, R., Asare, A. K., Sackey, S. O., Bannor, R., Kwame, A., Oko, S., & Osei-yeboah, R. (2020). Sleeping space matters : LLINs usage in Ghana Sleeping space matters : LLINs usage in Ghana ABSTRACT. *Pathogens and Global Health*, *00*(00), 1–8. https://doi.org/10.1080/20477724.2020.1776920
7. Barja, M. R., Cano, J., Ncogo, P., Nseng, G., Morales, M. A. S., Valladares, B., Riloha, M., & Benito, A. (2016). Determinants of delay in malaria care - seeking behaviour for children 15 years and under in Bata district , Equatorial Guinea. *Malaria Journal*, 1–8. https://doi.org/10.1186/s12936-016-1239-0
8. Bashar, K., Khondoker, Z. R., & Razzak, M. (2015). Biting Rhythms of Selected Mosquito Species (Diptera : Culicidae) in Open Access Biting Rhythms of Selected Mosquito Species (Diptera : Culicidae) in Jahangirnagar University , Bangladesh. *Journal of Mosquito Research*, *5*(8), 1–5. https://doi.org/10.5376/jmr.2015.05.0008
9. Bayoh, M., Mathias, D., Odiere, M., Mutuku, F., Kamau, L., & Gimnig, J. (2010). Anopheles gambiae: historical population decline associated with regional distribution of insecticide-treated bed nets in Western Nyanza Province, Kenya. *Malaria Journal*, *9*, 62.
10. Chan, C. W., Iata, H., Yaviong, J., Kalkoa, M., & Yamar, S. (2021). *SHORT REPORT Surveillance for malaria outbreak on malaria-eliminating islands in Tafea Province , Vanuatu after Tropical Cyclone Pam in 2015*. *2017*, 41–45. https://doi.org/10.1017/S0950268816002041
11. Chanda, E., Thomsen, E., Musapa, M., Kamuliwo, M., Brogdon, W., & Norris, D. (2016). An operational framework for insecticide resistance management planning. *Emerg Infect Dis.*, *22*, 773–9.
12. Chaves, L. F., Harrington, L. C., Keogh, C. L., Nguyen, A. M., & Kitron, U. D. (2010). Blood feeding patterns of mosquitoes : random or structured ? *Frontiers in Zoology*, *7*, 3.
13. Choi, K., Christian, R., Nardini, L., Wood, O., Agubuzo, E., & Muleba, M. (2014). Insecticide resistance and role in malaria transmission of Anopheles funestus populations from Zambia and Zimbabwe. *Parasites & Vectors*, *7*, 464.
14. Dunn, C., Le Mare, A., & Makungu, C. (2011). Malaria risk behaviours, socio-cultural practices and rural livelihoods in southern Tanzania: implications for bednet usage. *Soc Sci Med.*, *72*(3), 408–417.
15. Durnez, L., & Coosemans, M. (2013). Residual transmission of malaria: an old issue for new approaches. *Manguin Science InTechnology*, *3*, 1.
16. Eisele, T., Keating, J., Littrell, M., Larsen, D., & Macintyre, K. (2009). Assessment of insecticide-treated bednet use among children and pregnant women across 15 countries using standardized national surveys. *American Journal of Tropical Medicine and Hygiene*, *80*, 209–14.
17. Eisele, T., Larsen, D., & Steketee, R. (2010). Protective efficacy of interventions for preventing malaria mortality in children in Plasmodium falciparum endemic areas. *Int J Epidemiol.*, *39*(i88–i101), 5, 6.
18. Erlank, E., Koekemoer, L. L., & Coetzee, M. (2018). The importance of morphological identification of African

anopheline mosquitoes (Diptera : Culicidae) for malaria control programmes. *Malaria Journal*, 1–8. https://doi.org/10.1186/s12936-018-2189-5

19. Fana, S. A., Danladi, M., Bunza, A., Anka, S. A., & Imam, A. U. (2015). Prevalence and risk factors associated with malaria infection among pregnant women in a semi-urban community of north-western Nigeria. *Infectious Diseases of Poverty*, 4–8. https://doi.org/10.1186/s40249-015-0054-0
20. Getahun, A., Deribe, K., & Deribew, A. (2010). Determinants of delay in malaria treatment- seeking behaviour for under-five children in south-west Ethiopia : a case control study. *Malaria Journal*, *9*(1), 320. https://doi.org/10.1186/1475-2875-9-320
21. Grabowsky, M., Farrell, N., Hawley, W., Chimumbwa, J., Hoyer, S., & Wolkon, A. (2005). Integrating insecticide-treated bednets into a measles vaccination campaign achieves high, rapid and equitable coverage with direct and voucher-based methods. *Trop Med IntHealth*, *10*, 1151–60.
22. Gryseels, C., Durnez, L., Gerrets, R., Uk, S., Suon, S., Set, S., & Phoeuk, P. (2015). Re-imagining malaria : heterogeneity of human and mosquito behaviour in relation to residual malaria transmission in Cambodia. *Malaria Journal*, *14*(April), 165. https://doi.org/10.1186/s12936-015-0689-0
23. Gutiérrez-López, R., Martínez-de la Puente, J., & Gangoso, L. et al. (2019). Effects of host sex, body mass and infection by avian Plasmodium on the biting rate of two mosquito species with different feeding preferences. *Parasites Vectors*, *12*, 87. https://doi.org/https://doi.org/10.1186/s13071-019-3342-x
24. Hamon, J. (1963). Les moustiques anthropophiles de la r´egion de Bobo Dioulasso (R´epublique de Haute-Volta). Cycles d'agressivit´e et variations saisonni`eres. *Annual Society of Entomologiy France*, *132*, 85–144.
25. Kabbale, F., Akol, A., Kaddu, J., Matovu, E., & Onapa, A. (2016). Biting times of Plasmodium falciparum infected mosquitoes and transmission intensities following five years of insecticide-Treated bed nets use in Kamuli District, Uganda: Implications for malaria control. *International Journal of Mosquito Research*, *3*(4), 30–38.
26. Killeen, G. (2014). Characterizing, controlling and eliminating residual malaria transmission. *Malaria Journal*, *13*, 330.
27. Killeen, G., McKenzie, F., Foy, B., Bøgh, C., & Beier, J. (2001). The availability of potential hosts as a determinant of feeding behaviours and malaria transmission by African mosquito populations. Transactions of the Royal. *Society of Tropical Medicine and Hygiene*, *95*, 469–476.
28. Killeen, G., & Moore, S. (2012). Target product profiles for protecting against outdoor malaria transmission. *Malaria Journal*, *11*, 17.
29. Kirby, M. J., Green, P. M., & C, M. (2008). Risk factors for house-entry by malaria vectors in a rural town and satellite villages in the Gambia. *Malaria Journal*, *7*, 2.
30. Lefèvre, T., Gouagna, L., Dabire, K., Elguero, E., Fontenille, D., Renaud, F., & Costantini , C, Thomas, F. (2009). Beyond nature and nurture: phenotypic plasticity in blood-feeding behavior of Anopheles gambiae s.s. when humans are not readily accessible. *American Journal of Tropical Medicine and Hygiene*, *81*, 1023–1029.
31. Lorenz, C., Marques, T. C., & Sallum, M. A. . (2012). Morphometrical diagnosis of the malaria vectors Anopheles cruzii, An. homunculus and An. bellator. *Parasites and Vectors*, *5*, 257. https://doi.org/https://doi.org/10.1186/1756-3305-5-257
32. Loyola, E. G. L., Gonzalez Cero´ n, M. H. Rodrı´guez J. I. Arredondo Jimenez, S., S, B., & Bown, D. N. (1993). Anopheles albimanus (Diptera: Culicidae) host selection patterns in three ecological areas of the coastal plains of Chiapas, southern Mexico. *Journal of Medical Entomology*, *30*(518), 523.
33. Maliti, D. V., Marsden, C. D., Main, B. J., Govella, N. J., Yamasaki, Y., Collier, T. C., Kreppel, K., Chiu, J. C., Lanzaro, G. C., Ferguson, H. M., & Lee, Y. (2016). Investigating associations between biting time in the malaria vector Anopheles arabiensis Patton and single nucleotide polymorphisms in circadian clock genes : support for sub-structure among An . arabiensis in the Kilombero valley of Tanzania. *Parasites and Vectors*, *9*, 109. https://doi.org/10.1186/s13071-016-1394-8
34. Masaninga, F., Muleba, M., Masendu, H., Songolo, P., Mweene-Ndumba, I., & Mazaba-Liwewe, M. (2014). Distribution of yellow fever vectors in Northwestern and Western Provinces, Zambia. *Asian Pac J Trop Med.*, *7S1*, S88–92.
35. Masendu, H, Hunt, R., Koekemoer, L., Brooke, B., Govere, J., & Coetzee, M. (2005). Spatial and temporal distributions and insecticide susceptibility of malaria vectors in Zimbabwe. *African Entomology*, *13*, 25–34.
36. Masendu, HT, Sharp, B., Appleton, C., Chandiwana, S., & Chitono, C. (1997). Community perception of mosquitoes , malaria and its control in Binga and Gokwe Districts , Zimbabwe. *The Central African Journal of Mediicine*, *43*(3), 71.
37. Massey, N., Garrod, G., Wiebe, A., Henry, A., Huang, Z., Moyes, C., & Sinka, M. (2016). A global bionomic database for the dominant vectors of human malaria. *Scientific Data 3*. https://doi.org/160014. https://doi.org/10.1038/sdata.2016.14
38. Matowo, N., Moore, J., Mapua, S., Madumla, E., Moshi, I., & Kaindoa, E. (2013). Using a new odour-baited device to explore options for luring and killing outdoor-biting malaria vectors: a report on design and field evaluation of the Mosquito Landing Box. *Parasites and Vectors*, *6*, 137.
39. Maxwell, C., Wakibara, J., Tho, S., & CF, C. (1998).

Malaria-infective biting at different hours of the night. *Medical and Veterinary Entomology*, *12*, 325–7.
40. Mburu, M., Mzilahowa, T., Amoah, B., & Chifundo, D. (2019). Biting patterns of malaria vectors of the lower Shire valley, southern Malawi. *Acta Tropica*, *197*. https://doi.org/https://www.who.int/news-room/fact-sheets/detail/malaria
41. Milali, M. P., Lord, M. T. S., & Govella, N. J. (2017). Bites before and after bedtime can carry a high risk of human malaria infection. *Malaria Journal*, 1–10. https://doi.org/10.1186/s12936-017-1740-0
42. Moiroux, N., Gomez, M., Pennetier, C., Elanga, E., Djenontin, A., & F, C. (2012). Changes in Anopheles funestus biting behavior following universal coverage of long-lasting insecticidal nets in Benin. *Journal of Infectious Diseases*, *206*, 1622–9.
43. Monroe, A. (2015). Outdoor-sleeping and other night-time activities in northern Ghana : implications for residual transmission and malaria prevention. *Malaria Journal*, *14*, 35. https://doi.org/10.1186/s12936-015-0543-4
44. Monroe, A., Asamoah, O., Lam, Y., Koenker, H., Psychas, P., Lynch, M., Ricotta, E., Hornston, S., Berman, A., & Harvey, S. A. (2015). Outdoor-sleeping and other night-time activities in northern Ghana: Implications for residual transmission and malaria prevention. *Malaria Journal*, *14*, 35. https://doi.org/10.1186/s12936-015-0543-4
45. Moreno, M., Saavedra, M. P., Bickersmith, S. A., Prussing, C., Michalski, A., Rios, C. T., Vinetz, J. M., & Conn, J. E. (2017). Intensive trapping of blood-fed Anopheles darlingi in Amazonian Peru reveals unexpectedly high proportions of avian blood-meals. *PLOS Neglected Tropical Diseases*, *11*(2), 1–19. https://doi.org/10.1371/journal.pntd.0005337
46. Mpofu, S. (1985). Seasonal vector density and disease incidence patterns of malaria in an area of Zimbabwe. *Tropical Medicine and Hygiene*, *79*, 169–75.
47. Msellemu, D., Namango, H., Mwakalinga, V., Ntamatungiro, A., Mlacha, Y., & Mtema, Z. (2016). The epidemiology of residual Plasmodium falciparum malaria transmission and infection burden in an African city with high coverage of multiple vector control measures. *Malaria Journal*, *15*, 288.
48. Munhenga, G., Masendu, H., Brooke, B., Hunt, R., & Koekemoer, L. (2008). Pyrethroid resistance in the major malaria vector Anopheles arabiensis from Gwave, a malaria-endemic area in Zimbabwe. *Malaria Journal*, *7*, 247.
49. Navia-Gine, W. G., Loaiza, J. R., & Miller, M. J. (2013). Mosquito-host interactions during and after an outbreak of equine viral encephalitis in eastern Panama. *PLoS ONE*, *8*(12). https://doi.org/10.1371/journal.pone.0081788
50. Okumu, F., Madumla, E., John, A., Lwetoijera, D., & Sumaye, R. (2010). Attracting, trapping and killing disease-transmitting mosquitoes using odor-baited stations - The Ifakara Odor_Baited Stations. *Parasit Vectors*, *3*, 1.
51. Okwa, O. O., & Savage, A. A. (2018). Oviposition and Breeding Water Sites Preferences of Mosquitoes within Ojo area, Lagos State, Nigeria. *Biomed J Sci&Tech Res*, 7(5)-BJSTR MS.ID.001565. DOI: 10.26717/ BJSTR.201.
52. Ombugadu, A., Ekawu, R. ., Odey, S. ., Igboanugo, S. ., Luka, J., Njila, H. ., Ajah, L. ., Adejoh, V. ., Micah, E. ., Echor, B. ., Dogo, K. ., Ahmed, H. ., Ayim, J. ., Ewa, P. ., Aimankhu, O. ., Mafuyai, M., Yina, G. ., Pam, D. ., Lapang, M. ., … Angbalaga, G. . (2020). Feeding Behaviour of Mosquito Species in Mararraba-Akunza , Lafia Local Government Area , Nasarawa State , Nigeria. *Biomedical Journal of Science and Technology*, *25*(1), BJSTR. MS.ID.004133. https://doi.org/10.26717/BJSTR.2020.25.004133
53. Paintain, L. S., Awini, E., Addei, S., Kukula, V., Nikoi, C., Sarpong, D., Manyei, A. K., Yayemain, D., Rusamira, E., Agborson, J., Baffoe-wilmot, A., Bart-plange, C., Chatterjee, A., Gyapong, M., & Mangham-jefferies, L. (2014). Evaluation of a universal long-lasting insecticidal net (LLIN) distribution campaign in Ghana : cost effectiveness of distribution and hang-up activities. *Malaria Journal*, *13*, 71.
54. Pandian, R. S., & Chandrashekaran, M. K. (1980). Rhythms in the Biting Behaviour of a Mosquito Armigeres subalbatus. *Springer-Verlag*, *47*, 89–95.
55. Pates, H., & Curtis, C. (2005). Mosquito behavior and vector control. *Annual Review of Entomology*, *50*(February 2005), 53–70. https://doi.org/10.1146/annurev.ento.50.071803.130439
56. Pradhan, M., & Meherda, P. (2019). Malaria elimination drive in Odisha: hope for halting the transmission. *J Vector Borne Dis.*, *56*(1), 53.
57. Protopopoff, N., Van-Herp, M., Maes, P., Reid, T., Baza, D., & D'Alessandro, U. (2007). Vector control in a malaria epidemic occuring within a complex emergency sit_uation in Burundi: a case study. *Malar. J.*, *6*, 93–101.
58. Pryce, J., Richardson, M., & Lengeler, C. (2018). Insecticide-treated nets for preventing malaria. *Cochrane Database Syst Rev*, *11*, CD000363.
59. Randriamaherijaona, S., Raharinjatovo, J., & Boyer, S. (2017). Durability monitoring of long-lasting insecticidal (mosquito) nets (LLINs) in Madagascar: physical integrity and insecticidal activity. *Parasit Vectors.*, *10*, 564.
60. Rodríguez-Rodríguez, D., Katusele, M., Auwun, A., Marem, M., Robinson, L. J., Laman, M., Hetzel, M. W., & Pulford, J. (2021). Human Behavior, Livelihood, and Malaria Transmission in Two Sites of Papua New Guinea. *Journal of Infectious Diseases*, *223*(Suppl 2), S171–S186. https://doi.org/10.1093/infdis/jiaa402
61. Rodriguez-Rodriguez, D., Maraga, S., & Lorry, L. (2019). Repeated mosquito net distributions, improved

treatment, and trends in malaria cases in sentinel health facilities in Papua New Guinea. *Malaria JournalJ*, *18*, 364.
62. Sahu, S. S., Keshaowar, A. V., Thankachy, S., & Panigrahi, D. K. (2020). Evaluation of bio - efficacy and durability of long - lasting insecticidal nets distributed by malaria elimination programme in Eastern India. *Malaria Journal*, 1–9. https://doi.org/10.1186/s12936-020-03260-2
63. Sherrard-Smith, E., Skarp, J., & Beale, A. (2019). Mosquito feeding behavior and how it influences residual malaria transmission across Africa. *National Academy of Science*, *116*, 15086–95.
64. Solomon, T. I., Loha, E., Deressa, W., Gari, T., Overgaard, H. J., & Lindtj, B. (2019). *Low use of long-lasting insecticidal nets for malaria prevention in south-central Ethiopia : A community-based cohort study*. 15–24.
65. Tchouassi, D., Quakyi, I., Addison, E., Bosompem, K., Wilson, M., Appawu, M., & Al. (2012). Characterization of malaria transmission by vector populations for improved interventions during the dry season in the Kpone-on-Sea area of coastal Ghana. *Parasit Vectors*, *5*, 212.
66. Teklehaimanot, A., Sachs, J., & Curtis, C. (2007). Malaria control needs mass distribution of insecticidal bednets. *Lancet*, *369*, 2143–6.
67. Thomas, S., Ravishankaran, S., & Justin, N. A. J. A. (2017). Resting and feeding preferences of Anopheles stephensi in an urban setting, perennial for malaria. *Malar J*, 16, 111 https:/. https://doi.org//doi.org/10.1186/s12936-017-1764-5
68. Thomsen, E., Koimbu, G., & Pulford, J. (2017). Mosquito behavior change after distribution of bednets results in decreased protection against malaria exposure. *Journal of Infectious Diseases*, *215*, 790–7.
69. Tusting, L., Ippolito, M., Willey, B., Kleinschmidt, I., Dorsey, G., & Gosling, R. (2015). The evidence for improving housing to reduce malaria: a systematic review and meta-analysis. *Malaria Journal*, *14*, 209.
70. Wanzira, H., Eganyu, T., Mulebeke, R., Bukenya, F., Echodu, D., & Adoke, Y. (2018). Long lasting insecticidal bed nets ownership , access and use in a high malaria transmission setting before and after a mass distribution campaign in Uganda. *PLoS ONE*, 1–14.
71. WHO. (2013). Guidelines for laboratory and feld testing of long-lasting insecti_cidal nets. *Geneva: World Health Organization*.
72. WHO. (2015). *Global technical strategy for malaria 2016-2030*.
73. Wilke, A., Christe, R., Multini, L., Vidal, P., Wilk-da-Silva, R., & de Carvalho, G. (2016). Morphometric Wing Characters as a Tool for Mosquito Identification. *PLoS ONE*, *11*, 8. https://doi.org/e0161643. doi:10.1371/journal.pone.0161643)
74. Wilkerson, R., Linton, Y., Fonseca, D., Schultz, T., Price, D., & Strickman, D. (2015). Making mosquito taxonomy useful: a stable classification of tribe Aedini that balances utility with current knowledge of evolutionary relationships. *PLoS One*, *10*, e0133602.
75. Worrall, E., Were, V., Matope, A., Gama, E., Olewe, J., Mwambi, D., Desai, M., Kariuki, S., Buff, A. M., & Niessen, L. W. (2020). Coverage outcomes (effects), costs , cost- effectiveness , and equity of two combinations of long-lasting insecticidal net (LLIN) distribution channels in Kenya : a two-arm study under operational conditions. *BMC Public Health*, 1–16.
76. Yukich, J., Bennett, A., Keating, J., Yukich, R., Lynch, M., & Eisele, T. (2013). Planning long lasting insecticide treated net campaigns: should households' exist_ing nets be taken into account? *Parasit Vectors*, *6*, 174.
77. Zegers de Beyl, C., Koenker, H., Acosta, A., Onyefunafoa, E., Adegbe, E., & McCartney-Melstad, A. (2016). Multi-country comparison of delivery strategies for mass campaigns to achieve universal coverage with insecticide_treated nets: what works best? *Malar J.*, *15*, 58.
78. Zimmerman, R. H., Galardo, A. K. R., Lounibos, L. P., Arruda, M., & Wirtz, R. (2006). Bloodmeal hosts of Anopheles species (Diptera: Culicidae) in a malaria-endemic area of the Brazilian Amazon. *Journal of Medical Entomology*, *43*(5), 947–956. https://doi.org/10.1603/0022-2585(2006)43[947:BHOASD]2.0.CO;2