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ORIGINAL ARTICLE

Malaria Burden in an Area With High Ownership and Usage of Insecticide-Treated Nets in North Eastern Tanzania

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ABSTRACT

Background: Insecticide-treated nets and artemisinin combination therapy are just two of the measures taken to control malaria in Tanzania. Nevertheless, several regions of the nation still have high malaria burden. We aimed to identify the key factors contributing to the persistent malaria burden in rural areas of North Eastern Tanzania, despite high ownership and usage of insecticide-treated nets.

Methods: Three cross-sectional surveys were conducted in June 2021, October 2021 and February 2022. A total of 362 participants were recruited. The study included children aged between 2 and 10 years and adolescents/adults aged 11 to 70 years. The study was conducted in Kwamgwe ward site, which comprises of three villages namely Bondo, Kwadoya, and Kwamgwe .

A face-to-face interview was conducted. Demographic data, bed net ownership, bed netuse, and risk factors for malaria exposure were collected using a pre-tested questionnaire. The developed questionnaire was uploaded to the system, and data was collected electronically using the Open Data Kit (ODK) application. The blood sample from the finger-prick was used to test malaria parasites using a malaria rapid diagnostic test.

Results: Generally, malaria was higher in survey one, followed by survey two and three, with prevalence of 137 (37.8%), 90 (24.9%) and 86 (23.8%), respectively. Bondo had the highest malaria prevalence in all surveys. In Survey one, Kwamgwe had the highest rate of respondents using insecticide-treated nets, at 109(87.2%), P=.01. Insecticides treated nets usage was statistically higher in the age group between 18 to 45 years in all three surveys (P<.01). Participants were asked about using a insecticides treated net the night before. Surprisingly, the majority of individuals who tested positive for malaria slept under a bed net.

Conclusion: Despite extensive efforts to implement ITNs in Tanzania, malaria remains a significant challenge in areas like Kwamgwe, Handeni. High ITN ownership doesn't guarantee protection from getting malaria, highlighting the need for understanding human sleeping and mosquito biting behaviours for more effective interventions.

BACKGROUND

According to the World Health Organization (WHO), there were 249 million cases of malaria in 2022 across 85 countries, including Tanzania.[1] The number of malaria cases reached 241 million one year after the corona virus epidemic. Over 50% of malaria-related deaths worldwide occur in African countries, Tanzania included.[1] Tanzania annually reports an estimated 14 to 18 million cases of malaria, with approximately 120,000 associated deaths.[2] The most successful method for eradicating malaria worldwide continues to be increased vector control strategies, such as the use of insecticide-treated nets (ITN) or long-lasting insecticidal nets (LLIN) among at-risk communities as well as enhanced testing and treatment access.[3] According to the malaria indicator survey (MIS) report of 2021, the percentage of Tanzanian households with at least one ITN has consistently increased from 23% in 2004-2005 to 78% in 2017.[4,5] In the same way, the number of people who slept under an ITN the night before the survey rose from 15% in 2004/2005 to 52% in 2017.[4]

Generally, in Tanga, ITN ownership and usage are 88% and 67%, respectively, compared to 77% ownership in rural areas of Tanzania's mainland.[4] Tanzania began implementing the National Voucher Scheme (TNVS) in 2004 and proceeded to finance creative new approaches to achieving and maintaining universal bed net coverage,[6] and hence ceased in 2014.Then Tanzania piloted a School Net Programme (SNP) starting in 2013 through 2018 with 6 SNP rounds,[6–8] However, Tanga Region was not included in the SNP. World Vision, through its strategic objective to improve community capacity to prevent illnesses (including malaria) has distributed ITN to every household (HH) in Kwamgwe Ward in Tanga in 2020 (Personal Communication). However, Handeni, Tanga, remained to have high prevalence of

malaria and other vector borne diseases,[9,10] with an incidence rate of more than 150/1000 population.[11] In this study area, ITN ownership and use in connection with malaria prevalence had not been examined. Therefore, this study was designed to assess the burden of malaria in terms of prevalence as well as explored about ITN nets ownership and usage.

METHODS

Study Area

The study was conducted in Kwamgwe ward, Handeni rural district, Tanga region. Three villages were purposively selected namely Bondo, Kwadoya, and Kwamgwe.

Details of this study have been described elsewhere.[12] Briefly, Tanga is located at an elevation of 309 meters above sea level. Its coordinates are 5°22′60″ N and 38°34′60″ E in Degrees Minutes Seconds (DMS). The area has an annual rainfall of more than 1,212 mm with monthly rainfall peaks in April and May (wet season) of over 470 mm, and October to November (short rains) with over 250 mm.[13] Bondo is endemic to malaria with prevalence ranging from 10% to 50%,[10,14,15] while fever proportion is 14.8%.[16] Three villages have been purposively selected namely, Bondo, Kwamgwe and Kwadoya.

Sample Size Determination and Response Rate

We estimate an effective sample size of 365 assuming a specificity of 90%, sensitivity of 95%, precision level of 5%, confidence interval of 95% and a true prevalence of 20% (https://epitools.ausvet.com.au/prevalencess). The response rate was 99.1%

Study Procedures and Recruitment Strategy

The recruitment strategy and study procedures followed those described in our earlier work on dengue virus circulation in the same rural communities of Handeni District, Tanga, Tanzania.[12] Briefly, participants were recruited using a community-based approach targeting individuals residing in the selected villages. Prior to data collection, community sensitization was conducted in collaboration with local leaders to inform residents about the study objectives and procedures. Eligible participants, including children and adults, were enrolled voluntarily following informed consent or assent. Recruitment was designed to capture a representative sample of the population, with efforts made to ensure coverage across different sub-villages. Data collection was conducted at designated community areas, with flexible scheduling to accommodate participants' availability. The simple sampling was used to select participants until the desired sample size was reached.

Data Collection and Tool Piloting

Face-to-face interviews were conducted by trained interviewers using a structured questionnaire. The questionnaire was initially developed in English and subsequently translated into Swahili, the local language widely spoken in the study area, to ensure clear communication with participants. To verify clarity, relevance, and cultural appropriateness, the Swahili version of the questionnaire was pre-tested in a pilot study involving a small sample of individuals from a community similar to the study population but outside the selected villages. Feedback from the pre-test was used to refine the wording, structure, and flow of the questions, ensuring that they were easily understood and effectively captured the intended information.

The developed questionnaire was uploaded to the system and data was collected electronically using the Open Data Kit (ODK) application (ODK collect version 1.30.1; link: https://odk- collect.en.uptodown.com/android). Data for each of the participant were collected from every participant, except for those under 18 years where the guardian or caretaker answered the questions on their behalf. The data included age, sex, education, occupation, ITN ownership and usage. Community members participated in the three-screening surveys that were conducted ~4-month apart June 2021, October 2021 and February 2022. The study intended to answer the question "what factors contribute to the persistence of malaria burden in rural areas of North Eastern Tanzania despite high ownership and usage of insecticide-treated nets?".

Malaria Test

At the end of each interview, blood samples were taken from the participants for *P. falciparum* malaria screening using a rapid diagnostic test (SD BIOLINE Malaria Ag P.f/Pan). Malaria positive patients were treated with artemether-lumefantrine (20 mg artemether and 120 mg lumefantrine [Coartem®, Novartis Pharma AG, Basel, Switzerland]). Thick and thin blood smear for identification and quantification of malaria parasites were prepared following WHO standard method.[17] All blood smears were stained using the Giemsa protocol and screened for *Plasmodium falciparum* using light microscopy. Prepared Giemsa-stained films were read by two independent microscopists; in case of discrepancy a third reader was involved.

Statistical Analysis

The outcome variable was individual-level bed net use in a household with any bed net. Data were analyzed using the IBM SPSS Statistics for Windows version 24.0 (IBM Corp, Armonk, NY, USA). Pearson's chi-square test was used to assess the bivariate association between usage, ownership of ITNs and malaria prevalence in each survey. A P value of <0.05 was considered statistically significant.

Ethical Approval

Ethical approval for the study was obtained from the Kilimanjaro Christian Medical University College Research and Ethics Review Committee (CRERC), under certificate number 2492, and from the National Institute of Medical Research (NIMR), with certificate number NIMR/HQ/R.8a/Vol.IX/3651. Permission to carry out the study was also granted by the Handeni district medical officer (DMO) and the respective village leaders. Written informed consent was secured from all adult participants. For participants aged 7 to 17 years, who were legally unable to provide consent, assent was obtained, with parents or guardians additionally, providing consent on their behalf.

RESULTS

Socio-Demographic Characteristic of Participant

The sociodemographic characteristics of the study participants are reported as detailed elsewhere.[12] In brief,

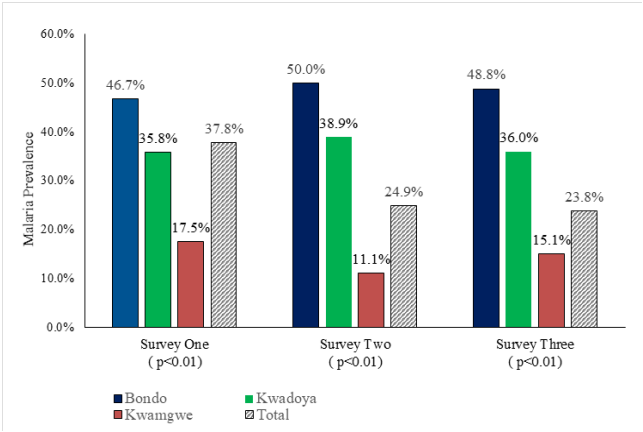
the study included 362 participants of which most of them 144 (39.8%) were from Bondo. Most of the participants were adults (above 18 years old) 186 (51.4%). Majority of them were women 209 (57.7%). Most of the people who took part didn't go to school or were children 128 (35.4%), and most of them were farmers 325 (89.8%).

Malaria Prevalence

Generally, malaria was higher in survey one, followed by survey two and lastly survey three with prevalence of 137 (37.8%), 90 (24.9%) and 86 (23.8%) respectively. Bondo had the highest malaria prevalence in all surveys (Figure 1).

In survey one, a total of 64 (46.7%) participants had positive mRDT in Bondo, followed by Kwadoya 49 (35.8%) and Kwamgwe 24 (17.5%), $\chi 2=29.85$, $p<0.01$). In survey two, 45 (50.0%) participants had malaria in Bondo, followed by Kwadoya 35 (38.9%), and then Kwamgwe 10 (11.1%), $\chi 2=30.29$, $p<0.01$. In survey three, (42 (48.8%) participants had malaria in Bondo, followed by Kwadoya 31 (36.0%), and then Kwamgwe (13 (15.1%) ($\chi 2=19.34$, $p<0.01$), Figure 1.

FIGURE 1: Malaria Prevalence in Three Villages of Handeni Rural District



Insecticide-Treated Net Ownership and Usage Among Respondents

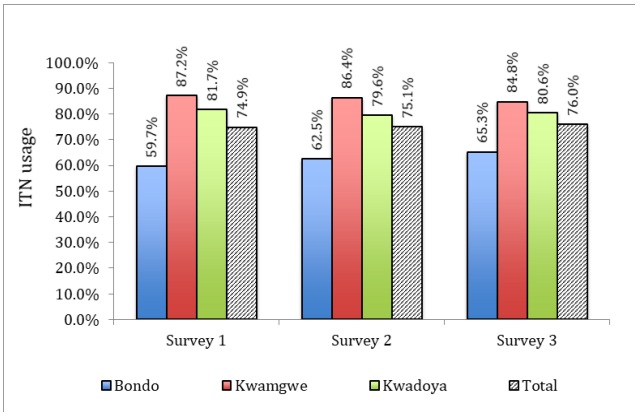
The present study has revealed, a greater rate of ITN ownership 86 (92.5%) in Kwadoya than Bondo 131 (91.0%) or Kwamgwe 113 (90.4%) ($P>0.05$). ITN ownership was statistically higher in the age group between 18 to 45 years. There we no statistically significant difference in ITN ownership for sex and education level ($P>0.05$), Table 1.

In Survey one, Kwamgwe had the highest rate of respondents using ITNs, 109 (87.2%), followed by Kwadoya 76 (81.7%), and Bondo 86 (59.7%), $P=.01$. Likewise, in Survey two and three, Kwamgwe had the highest rate of respondents using ITN 108 (86.4%) and 106 (84.8%), followed by Kwadoya 74 (79.6%) and 75 (80.6%), and Bondo 90 (62.5%) and 94 (65.3%) respectively, $P=.01$, Figure 2. Equally, ITN usage was statistically significantly higher in the age group between 18 to 45 years during all the three surveys, ($P<0.01$), Table 1.

Insecticide-Treated Net Usage Among Malaria positives in Three Surveys

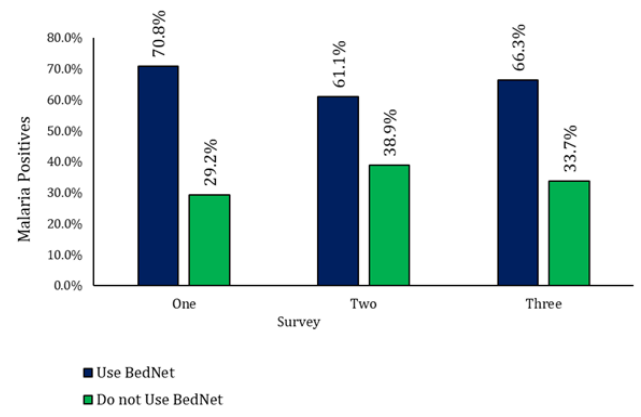
Participants in all three surveys were asked about having used an ITN the night before. Surprisingly, the majority of individuals who tested positive for malaria slept under a bed net. In surveys one, two, and three, participants were positive for malaria in 97/137 (70.8%), $P=0.04$, 55/90, (61.1%), $P=0.01$), and 57/86 (68.3%), $P=0.05$, respectively (Figure 3).

FIGURE 2: Insecticide-Treated Net Ownership and Usage Among Respondents



Abbreviation: ITN, Insecticide-Treated Nets

FIGURE 3: Insecticide-Treated Net Usage Among Malaria Positives During the Three Surveys



Abbreviation: ITNs, Insecticide Treated Nets

TABLE 1: Association of ITN Ownership/Usage and Demographic Characteristics

Variable	ITN Ownership % (n)			ITNU sage % (n)		
	Survey One	Survey Two	Survey Three	Survey One	Survey Two	Survey Three
Sex						
Male	42.1 (139)	42.1 (139)	42.1 (139)	43.2 (117)	43.4 (118)	43.6 (120)
Female	57.9 (191)	57.9 (191)	57.9 (191)	56.8 (154)	56.6 (154)	56.4 (155)
P value	*P*>.05	*P*>.05	*P*>.05	*P*>.05	*P*>.05	*P*>0.05
Age category						
≤5 years	13.0 (43)	13.0 (43)	13.0 (43)	14.0 (38)	14.3 (39)	13.4 (37)
6-10	20.0 (66)	20.0 (66)	20.0 (66)	19.6 (53)	19.5 (53)	20.4 (56)
11-17	17.6 (58)	17.6 (58)	17.6 (58)	18.5 (50)	18.8 (51)	19.3 (53)
18-49	30.6 (101)	30.6 (101)	30.6 (101)	30.6 (83)	30.1 (82)	29.8 (82)
≥50 years	18.8 (62)	18.8 (62)	18.8 (62)	17.3 (47)	17.3 (47)	17.1 (47)
Chi-square, & P value	X^2=15.29 *P*=.004	X^2=15.29 *P*=.004	X^2=15.29 *P*=.004	X^2=11.28 *P*=.02	X^2=13.13 *P*=.01	X^2=15.52 *P*=.004
Education						
Primary	57.9 (191)	57.9 (191)	57.9 (191)	59.4 (161)	59.9 (163)	60.0 (165)
Secondary	4.8 (16)	4.8 (16)	4.8 (16)	5.2 (14)	4.8 (13)	5.1 (14)
Tertiary	0.9 (3)	0.9 (3)	0.9 (3)	0.7 (2)	0.7 (2)	0.7 (2)
At school/ Kindergarten/ Illiterate	36.4 (120)	36.4 (120)	36.4 (120)	34.7 (94)	34.6 (94)	34.2 (94)
Chi-square, & P value	*P*>.05	*P*>.05	*P*>.05	*P*>.05	*P* >.05	*P*>.05

DISCUSSION

The Tanzanian Government, through the National Malaria Control Program (NMCP) and other stakeholders, has successfully implemented ITNs in targeted at-risk populations as well as in the general population.[5,18] Despite all these efforts made, malaria has been a problem in some areas/villages in Tanga.[10,19–21] The study aimed to explore the use and ownership of ITNs as well as the burden of malaria in terms of prevalence.

Malaria Prevalence

Bondo area showed a notably higher malaria prevalence compared to the previous studies conducted in the same area. The prevalence in Bondo was found to be three times higher than previously reported at 8.6%,[10] surpassing even the national average of 3.1%.[22] The variations observed in malaria prevalence between the surveyed villages highlight the intricate nature of malaria transmission dynamics, emphasizing the necessity for localized interventions tailored to specific contexts. Bondo exhibited a considerably higher malaria prevalence compared to Kwamgwe and Kwadoya. This disparity may be attributed to several factors, including differences in population density and environmental conditions that favor mosquito breeding. For instance, Bondo's higher population density could lead to increased human-vector contact, while the presence of more stagnant water bodies in and around the village might create additional breeding sites for mosquitoes. The findings also shed light on the temporal aspect of malaria transmission, revealing a year-round occurrence with a notable peak from April to June, corresponding with the long rainy season in Tanga (March-July). This pattern suggests a holoendemic nature of malaria in the study area, with Bondo village potentially acting as a hotspot for malaria infection. The higher malaria prevalence in rural areas is often linked to favorable conditions for malaria transmission, such as stagnant water bodies that serve as breeding sites for mosquito vectors.

Ownership

Findings from this study indicate the widespread availability of ITNs in the research area; an evidence for the intensive efforts of the Tanzanian Government and partnering organizations which have distributed ITNs free of charge.[5,23]

The WHO recommends universal access and utilization of appropriate interventions for populations at risk of malaria, aiming for a ratio of one bed net for every 1.8 individuals.[24] Moreover, the NMCP has set targets to increase ownership, aiming for at least 80% coverage by 2020 and 100% by 2022–2023.[22] In this study, an impressive majority over 90% of research participants reported owning a bed net. This achievement surpasses the national average, indicating that ITN coverage is notably higher and approaches the WHO's recommended threshold. In comparison to a previous study conducted in Tanga, where rural areas reported a bed net ownership rate of 49.7%,[25] the ownership rate observed in this study is significantly higher. This disparity can be attributed to the intensified efforts aimed at achieving universal coverage, specifically, participants aged 18-49 years were found to be the most frequent users of ITNs, possibly reflecting targeted distribution programs tailored to this demographic subgroup, considering that the majority of the population falls within the reproductive age group.

Association of ITN Use With Malaria

The association between bed net usage and malaria prevalence has been a subject of significant interest in public health research. In this study, we explored the relationship between bed net utilization and malaria prevalence in three villages: Bondo, Kwamgwe, and Kwadoya, in Tanzania. Our findings contribute to the growing body of evidence regarding the effectiveness of ITNs in reducing malaria transmission.

In this study, it was observed that a majority of participants who tested positive for malaria had reported sleeping under a bed net the night before the survey. This finding underscores the persistence of malaria despite the widespread use of ITNs, highlighting the complex nature of disease transmission dynamics. Although ITNs are known to provide protection to persons who sleep under them, it is important to note that malaria vectors do not always follow the sleeping pattern of humans. Mosquitoes may exhibit biting behaviour earlier in the evening, before individuals utilize ITNs.[26,27] Consequently, individuals may still contract malaria despite consistent bed net use. The results suggest that several factors may contribute to the occurrence of malaria among individuals who use ITNs. Firstly, it is possible that self-reported ITN usage during questionnaire sessions may led to overestimation of actual usage rates. Furthermore, the emergence of insecticide resistance among mosquito populations poses a significant challenge to the effectiveness of ITNs.[28] Additionally, shifts in human and mosquito behaviour, such as outdoor activities during peak mosquito biting times, could increase the risk of infection even among bed net users. Moreover, decreased bioefficacy and durability of ITNs over time may compromise their effectiveness in preventing mosquito bites and malaria transmission.[28]

Therefore, it is imperative to further investigate both human sleeping behaviours and mosquito biting patterns to better understand the observed association between bed net use and malaria prevalence. This knowledge is crucial for refining malaria control strategies and enhancing the effectiveness of interventions aimed at reducing malaria transmission. Consequently, there is a pressing need for innovative strategies to enhance the utilization of ITNs, which should be integrated into the malaria control agenda,[28–30] as well as extensive communications initiatives aimed at influencing social and behavioural norms in order to raise awareness and address prevalent practices in malaria endemic areas. In a qualitative study carried out in Dar es Saalam, it was revealed that people's perceptions of contracting malaria despite ITN usage were linked to spending evenings outdoors, often for social activities such as resting and public drinking venues, as these are all things that people do when they are outside their homes.[31] These behaviours coincide with outdoor exposure, increasing the risk of malaria transmission.[31–33]

Strength and Limitation

In the current study, we inquired as to whether or not participants had used an ITN the night before the survey, and whether or not they owned an ITN (ITN was available for sleeping space). ITN ownership and sleeping under it the night before the survey were self-reported. Participants could have answered "no" to a question with the expectation that they would later receive another bed net because the results of this study were based on asking questions rather than viewing mounted ITNs. A survey of households might be appropriate. Therefore, human sleeping time/behaviour and mosquito biting behaviour need to further be investigated. This will reveal at what time is the net proactive.

CONCLUSIONS

Despite substantial efforts by the Tanzanian Government and partners to achieve universal coverage of ITNs, malaria remains a persistent public health challenge in specific localities, particularly in Kwamgwe, Handeni. Our findings reveal a higher malaria prevalence than previously documented, with transmission occurring all year-round and peaking notably between April and June. Although ITN ownership exceeds 90%, the continued association between net usage and malaria infection highlights the complex interplay of factors driving transmission. This underscores the urgent need for deeper exploration of human sleeping behaviours and vector biting patterns to optimize intervention strategies. To effectively reduce malaria burden, innovative approaches combined with targeted behavioural change communication are essential to address local practices and enhance the protective efficacy of ITNs within these communities.

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