Determinants for Exposure to Mosquitoes and Bed Net Use Behavior in the Context of the New Nets Project in Rwanda

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Abstract

Determinants for Exposure to Mosquitoes and Bed Net Use Behavior in the Context of the New Nets Project in Rwanda

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Abstract

Background: The effectiveness of any insecticide-treated mosquito net (ITN) or long-lasting insecticidal net (LLIN) is greatly influenced by the consistency of its use. Insights from user perspectives are crucial for monitoring and informing implementation strategies, including effective marketing and educational campaigns focused on using nets to reduce malaria transmission. Using qualitative data from Rwanda, this study seeks to understand how daily activities are related to risk of malaria transmission as well as understand facilitators and barriers to effective LLIN usage.

Methods: Research Assistants conducted 18 key informant interviews (KIIs) and three focus group discussions (FGDs) with a total of 46 participants. KIIs and FGDs used semi-structured

interview guides that covered topics related to activities that participants engaged in at various times of the day, knowledge of malaria treatment and prevention, beliefs around which types of people are more likely to get malaria, direct experience with malaria, and bed net acquisition and use. KIIs and FGDs were conducted in Kinyarwanda, and audio recorded. The research team used NVivo 1.3.1 to code transcripts.

Results: Participants reported engaging in routine activities which put them at risk for malaria during times when *Anopheles* mosquitoes were more likely to bite, such as leaving early in the morning to work in the hills, preparing dinner in the evening, coming home from the market late, working as night security guards, fetching water, going out to bars or visiting friends. Study participants were well aware that mosquitoes caused malaria, knew about or had directly experienced malaria symptoms, and knew why and how to use a bed net. The biggest barrier to using a net was lack of access. Other common reasons for not using a net include physical discomfort or concerns with the net chemicals, logistical challenges of hanging the net, or engaging in routine work or social activities during mosquito biting times.

Conclusions: The largest barrier to net use was lack of access to one, which could be remedied by allowing all socioeconomic groups to be eligible to receive a net, and to ensure that there is one net distributed per sleeping space. Government distributions of nets should include both conical and rectangular nets as options to reduce logistical barriers of hanging a net. Results from this study could assist the National Malaria Control Program in Rwanda and to improve the impact of its bed net program.

Key Words: Malaria, qualitative research, Rwanda, bed net

Introduction

In 2019, there were an estimated 229 million cases of malaria worldwide, resulting in approximately 409,000 deaths, 67% of which were children under five.[1] In 2018, Africa accounted for 94% of malaria cases and deaths, making it an important region in which to focus prevention and treatment efforts.[1] In Rwanda, malaria is one of the top 10 causes of mortality, and malaria is the third highest contributor to disability-adjusted life years (DALYs).[2] Although prevalence among children under five declined from 2.6% in 2008 to 1.4% in 2010,[3] it increased to 7% in 2017.[4] The Malaria, Neglected Tropical Diseases and Other Parasitic Diseases Division (MOPDD) of the Rwanda Biomedical Center[5] found that malaria was increasing due to mosquito resistance to insecticide, erratic application of IRS, lack of mosquito nets and more precipitation.[3]

Since the 1970s[6] using insecticide treated bed nets (ITNs) has been promoted as one of the four main interventions for malaria used in countries that have a high burden of malaria, along with case management, intermittent preventive treatment of malaria in pregnant women (IPTp), and indoor residual spraying (IRS).[7] Generally, *Anopheles* mosquitoes that carry *Plasmodium falciparum,* the parasite that causes the most severe form of malaria,[8] are known to bite at night, mostly during the hours of 9pm to 5am.[9] Thus, bed nets offer significant malaria protection potential during typical sleeping hours. While the insecticide in ITNs is effective for 6-12 months,[6] the more recently developed long-lasting insecticidal nets (LLINs), in which insecticide is included within the net fibers, last for three or more years.[10] Both ITNs and LLINs prevent malaria in two ways: 1) create a barrier between humans and mosquitoes to prevent mosquito bites and 2) exterminate mosquitoes that land on the nets.[11] A study by Yang et al. found that overall, LLINs reduced malaria by 56%, while ITNs reduced malaria by 41%.[12] However,

mosquitoes have developed resistance to the insecticides most typically used in both of these types of nets, which may reduce their continued effectiveness for vector control.[13]

There is some evidence that using bed nets treated with more than one type of insecticide can mitigate the problem of mosquito insecticide resistance. A study in Burkina Faso showed that a dual active-ingredient LLIN reduced clinical malaria incidence by 12% more than LLINs containing only pyrethroid insecticide (incidence rate ratio 0.88, [95% CI 0.77 – 0.99, p=0.04]),[14] and a study in Tanzania found that malaria prevalence was 13% lower in the groups that received dual-ingredient LLINs (29% prevalence) compared to those that received standard LLINs (42% prevalence) (OR 0.37, 95% CI 0.21-0.65).[15] However, such comparative studies have been few.

The effectiveness of any ITN or LLIN is greatly influenced by the consistency of its use. Globally, previous qualitative studies have identified common obstacles to using nets, which include not having access to a net that had regularly been used, experiencing nets as too uncomfortable or too hot to use, decreased motivation for using nets in seasons when there are fewer mosquitoes disrupting sleep, sleeping in a different place than usual, and having difficulty with setting up nets.[16–23] In Rwanda, qualitative studies conducted in Bugesera and Nyanza districts found similar reasons for non-use of nets, in addition to reports of non-use because nets were damaged, were associated with bed bugs, or were being used for other reasons, such as chicken pens.[24–26]

Quantitative studies have also looked at explanatory variables to predict net use.[27–29] Aspects such as age, socioeconomic status, use of other malaria prevention measures and access to nets

all had an impact on the use of nets. Starting with access, children under five that lived in households with two or more nets were more likely to sleep under a net, which led authors to believe that when there was only one net in a household, family members that were above age five were using it.[30] Regarding demographic variables, a study in Uganda found that people younger than age 30 were more likely to use bed nets, which the authors suggest may be because younger people are more receptive to messages.[31] Socioeconomic status was found to be a predictor in that those who are in a higher socioeconomic category are more likely to use a net, potentially due to the fact that they have more money available to purchase a net, or that they are more likely to follow behavior change communication messages.[31,32] Finally, in relation to other intervention measures, those who lived in households that also used mosquito coils were less likely to use nets, which the authors believe may mean people use coils rather than nets.[27]

The current study will add to the body of literature on qualitative bed net use studies in Rwanda. As new bed net technologies emerge over time and information sources in communities and social norms evolve, it is important to continue to explore user perspectives.[33] Insights from user perspectives are crucial for monitoring and informing implementation strategies, including effective marketing and educational campaigns focused on using nets to reduce malaria transmission. This study seeks to understand facilitators and barriers to effective Long-Lasting Insecticidal Net (LLIN) usage as well as to describe how daily activities are related to risk of malaria transmission. Results from this study could assist the National Malaria Control Program in Rwanda and the New Nets Project to improve the impact of future bed net distributions.

Methods

Study Design and Setting

The present study is nested within the New Nets Project parent study. The New Nets Project is funded by the Bill and Melinda Gates Foundation, Unitaid and Global Fund. Collaborators include the Innovative Vector Control Consortium, Population Services International (PSI), Imperial College, PATH, Liverpool School of Tropical Medicine, the London School of Tropical Medicine (LSHTM), National Center for Research and Training on Malaria [Centre National de Recherche et de Formation sur le Paludisme] (CNRFP) in Burkina Faso, University of Rwanda and Tulane University. The MPH student was affiliated with PATH, first as an intern and then as a temporary employee.

The New Nets Project parent study is testing two dual-ingredient LLINs that have achieved WHO prequalification, Interceptor G2 (IG2) nets, with pyrethroid (alpha-cypermethrin) and a pyrrole (chlorfenapyr) insecticide, and Royal Guard nets, which contain a pyrethroid (alpha-cypermethrin) and an insect growth regulator (pyriproxyfen). Interceptor G2 and Royal Guard Nets are manufactured as both conical and rectangular,[34,35] though the new nets distributed as part of this study are rectangular.

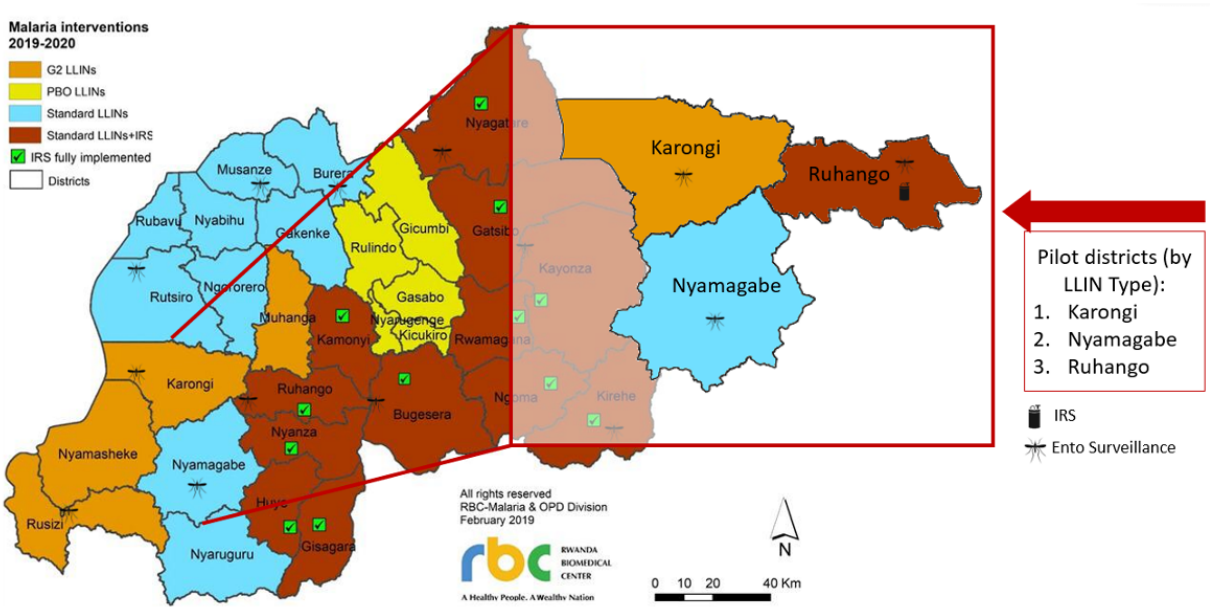
The Project seeks to establish evidence of effectiveness (and cost-effectiveness) of both of these nets through observational pilot studies in conjunction with national LLIN distributions in Burkina Faso, Mozambique, Rwanda and Nigeria. The parent study consists of five components: epidemiology, entomology, anthropology, cost-effectiveness, and durability monitoring.

The anthropological portion of the study in Rwanda will collect data twice per year, once during the rainy season (March/April) and once during the dry season (July/August). The data for the present study was collected during the first round of qualitative data collection in Rwanda during the dry season in 2020 after the national bed net distribution. Due to the SARS-CoV-2 pandemic, there was a lockdown, so data collection was postponed from March – April 2020 to July – August 2020. The study team ensured that study staff and participants used PPE, and the study team had to ask for additional permissions from authorities in order to be provided clearance for research activities. Data were collected via key informant interviews (KIIs) and focus group discussions (FGDs).

Project coordinators, in addition to an Anthropologist from the Liverpool School of Tropical Medicine (LSTM) conducted a week-long data collection training for study Team Leaders and Research Assistants. Research Assistants were trained in study procedures, including informed consent, household recruitment, conducting KIIs and FGDs, and confidentiality principles in research. The Team Leaders were trained in study procedures, specific supervision functions, communication channels with the team and confidentiality principles in research. The Anthropologist from LSTM provided data quality assurance when the interviews were complete.

Data collection took place in Western and Southern Rwanda, in the districts of Karongi, which received IG2 LLINs, Nyamagabe District, which received standard LLINs only, and Ruhango, which received standard LLINs in addition to IRS. The decisions on where and which type of net to distribute were made by the National Malaria Control Program (NMCP). The study was

observational due to the fact that the NMCP made the decisions regarding which interventions to implement in each location, so the parent study is investigating the impact of those interventions.



The New Nets Project team, along with the health center, selected three villages in each of the three districts in which to conduct the study. The villages are remote, with only some of them having access to running water. Most people in the villages make a living through farming and animal husbandry.

Study Subjects/Population

Participants in this qualitative study were those who live in the study villages described above. Inclusion criteria included individuals of both sexes, not belonging to vulnerable categories (those with cognitive impairment or any other person for whom full and open consent could not

be guaranteed), and at least 18 years or older. The exclusion criteria were individuals unwilling and/or unable to give consent, vulnerable categories and individuals below the age of 18 (due to the age of consent).

Sampling strategy

Research assistants who lived in each study district for up to four months each year spoke with those in the community on an informal basis. From those conversations, they purposively sampled a subset of people for KIIs who typically engaged in a diverse array of daily activities, for instance, fishing, childcare, and farming. After KIIs were completed, FGDs were conducted with a subset of the participants of the KIIs. In addition, the research assistants used the chain referral method to recruit additional participants for the FGDs.

Sample size calculations for each method were based on study team experience and knowledge of population bed net usage and estimates of reaching informational saturation. Table 1 summarizes the number of KIIs and FGDs by district.

Data Collection

KIIs and FGDs were conducted in Kinyarwanda, and audio recorded. For KIIs, prior to each interview, the Research Assistants gave an introduction to the project, assured the participants that the interviews would remain confidential and completed the informed consent process with the heads of households. Informed consent forms were approved by the Rwandan National Ethics Committee and were translated into Kinyarwanda. Following the informed consent process, the Research Assistants recorded demographic information, and used a semi-structured

interview guide. The anthropologist from LSTM developed these semi-structured interview guides for the KIIs and FGDs based on prior field experience. Both KIIs and FGDs covered topics related to activities that participants engaged in at various times of the day (later categorized into day time activity from 6am – 6pm and night time activity from 6pm to 6am), knowledge of malaria treatment and prevention, beliefs around which types of people are more likely to get malaria, direct experience with malaria, and bed net acquisition and use. The interviewer closed the KIIs after a maximum of 90 minutes.

For FGDs, there were between 6 and 10 participants. The moderators provided a brief description of the project , encouraged the participants not to share what had been discussed outside of the FGD, and read and documented signatures for informed consent. The moderator recorded the demographic information of the participants, and led the discussion using the FGD guide, for a maximum of two hours. In addition to the subjects covered during KIIs, the FGD guides explored how participants would prioritize bed net usage and treatment in a hypothetical family consisting of parents and male and female children of various ages.

Data Management and Analysis

Audio recordings were transcribed verbatim, and then translated to English. PATH staff members in Rwanda sent translated transcripts to the PATH director of Qualitative research for the New Nets Project, the Anthropologist from LSTM, and the MPH student for analysis and quality assurance checks.

KII and FGD transcripts were uploaded into NVivo 1.3.1. The initial codebook was developed by the same LSTM researcher who trained the qualitative research assistants and was based on her prior studies relating to bed net use. The MPH student added inductive codes to the codebook after repeated readings of the transcripts and in consultation with the Anthropologist from LSTM. Transcripts were analyzed using thematic content analysis.

Each transcript was coded by one member of the analysis team, and reviewed by a second member of the study team. The reviewer made note of any disagreements with coding done by the primary coder, and disagreements were resolved through discussion and consensus.

Ethical Approval

The study protocol was reviewed and approved by the WHO Research Ethics Review Committee, PATH's Research Ethics Committee and the Rwanda National Ethics Committee. The UW Human Subjects Review Board determined that there was no need for UW IRB approval due to the fact that the MPH student received de-identified transcripts from PATH, and the student did not interact with any of the research participants. Informed consent was obtained from research participants prior to KIIs and FGDs.

Results

This study analyzed data from 18 key informant interviews and three focus group discussions with a total of 46 participants. The demographic information for KII and FGD participants are outlined in table 2. The majority of participants worked as subsistence farmers, owned livestock, and/or engaged in various types of casual labor. Others worked as night guards, teachers, road

workers, tailors, in mining, or performed as members of a cultural troupe that performs songs about health.

General knowledge of malaria

In general, participants correctly identified that mosquitoes cause malaria, with some specifying *Anopheles* mosquitoes and others specifying *Plasmodium* parasites. Other causes of malaria listed were poor sanitation, lack of nutrition, transmission through drinking dirty water, cold weather, and insects in general. Participants also identified environmental factors associated with mosquitoes and their breeding grounds, including bushes, swamps, banana trees, Lake Kivu, forests, wells, stagnant water, pits, excreta from livestock, a coffee plantation, and macadamia plantations. Most participants listed common malaria symptoms, such as headache, fever, chills, body pain, nausea, vomiting, and malaise. Almost all participants reported having had malaria themselves.

> *"Respondent: I know malaria as disease which is common in this area; and it's a disease that is dangerous. We suffer [from] malaria frequently; and whenever it attacks people, it become[s] serious. Even preventing it, is not so easy; in fact, malaria is the most common disease in our village." (IDI 6, Karongi)*

Knowledge and use of prevention measures

Nearly all of the participants mentioned at least one prevention measure, with examples such as using bed nets, maintaining sanitation and hygiene, clearing stagnant water, closing doors and windows early in the evening so mosquitoes would not be able to enter the house, clearing bushes around the house, wearing long clothes, drying dishes, and using mosquito repellant

creams and coils. The majority of participants stated that they used prevention methods for malaria.

> *"We prevent malaria in our homes by clearing bushes around our homes; and also removing old [jerrycans], pots, and other unused utensils; in which water can be collected, and then serve as breeding sites for mosquitoes. We also have to cover all pits around the home, where water can collect and serves [as] breeding sites for mosquitoes. Another measure is to sleep under bed nets always; and closing windows early in [the] evening, so that mosquitoes [do] not enter the house..." (FGD Karongi)*

Barriers to bed net acquisition

Participants reported several complications of the bed net distribution process which limited universal bed net access. Most of the participants who had nets reported receiving a free net from the government distribution system. However, study participants emphasized that only individuals in the lower two government-defined socio-economic categories, referred to as Ubudehe categories, receive bed nets for free from the government distribution. Those in the higher two Ubudehe categories are not given free nets, though many in category 3 reported being unable to afford to buy nets elsewhere. Another access challenge reported was being unable to receive nets in one's current location because of being registered in another location; in order to collect their nets, individuals would have to go back to the village where they were originally registered.

Some study participants were successful in accessing nets outside of the government distributions channels, for example from an ante-natal clinic, or through purchase from a pharmacy or from individuals selling nets they had been given for free. However, other participants described not being able to find nets outside of the government free distribution channels. Participants reported some families were given more nets than they needed, whilst other households received fewer nets than they needed. Participants claimed that some people tricked community health workers (CHWs) into giving them more nets from the distribution than they needed, so that they could sell the additional nets. Some participants also said that some CHWs registered giving a household more nets than the household actually received.

Facilitators of Bed Net Use Among Bed Net Owners

Our study participants described several facilitators of bed net use, mostly related to beliefs of health-related benefits, including the belief that the net helps to avoid mosquito bites, the perception that participants get diagnosed with malaria less frequently when they use a net, the perception that nets diminish the annoyance of mosquitoes buzzing, the belief that children are more susceptible to malaria and should sleep under a net, and the perception that having a net protects against bad health and being cold. When the interviewer asked participants whether they stopped using a net during certain seasons, all who replied stated that they use a bed net during all seasons of the year.

> *"I have three bed nets, corresponding to three beds we have in this home. Two are new bed nets, which were given to me recently, and one is old, it was given to me during the previous supply. But only two beds have bed nets hanged over them. The third bed is reserved for visitors; so when we get a visitor that's when we hang [a] bed net over that*

bed. In brief everyone in this home [has] to sleep under bed nets; including children and visitors." (IDI 1, Karongi)

Participants also described how different styles of nets can facilitate use. Generally, participants preferred conical nets because they were easier to hang, for example by tying a rope from the middle of the net to the roof. A few people said that rectangular nets are better for big bedrooms, but worse for small houses. One person stated that rectangular nets are better because when things fall from the ceiling, it is easier to collect them when they fall onto a suspended surface.

Barriers to Bed Net Use Among Bed Net Owners

Although all participants stated that it was important to use nets, they also listed a variety of barriers to using them. Some individuals who owned nets did not use them because they believed them inadequate. For example, some believed nets were no longer effective once the chemicals had expired or after the nets had been washed two or three times.

Other participants reported not using nets because they caused physical discomfort. For example, some participants reported waking up with pruritic wheals on their skin, which they believe were caused by the chemicals in nets. A few others cited irritation in general, difficulty breathing under a net, being affected by the smell from a net, or being too hot when using it.

Several participants reported logistical barriers to net use. One participant whose children sleep on the floor reported the challenge of hanging the net so that it did not touch their faces. Another participant stated that the sitting room where the children sleep is too small a space in which to hang a net. Another participant reported difficulty of hanging a rectangular net in a small house.

Finally, one participant described living in a one room house where family members sleep in the same room where they cook; the smoke from the cooking fire turned the net black, and the family stopped using it.

Finally, some participants reported lack of consistent net use due to forgetfulness or because they arrive home late and are too tired to adjust the net over their sleeping space.

> *"But my elder son, most often like[s] going out in evening, to converse with his friends at the trading centre near the main high way; and then return[s] home in [the] late evening hours. And sometimes he may find his siblings sleeping, and then he goes to bed without spreading the bed net over the bed. And when in the morning I go to their house, I ... find [the] bed net not spread on their bed; you know they sleep in their own house. Maybe that could be the reason why he got malaria ... last week." (IDI 6, Runyinya)*

Prioritization of Available Nets

Participants reported households frequently did not have an adequate number of nets to cover each member. In describing how net access should be prioritized among those in the household, participants were split in prioritizing younger versus older members of a household. Some participants prioritized the use of nets for adults over children, believing older adults to have lower immunity, or because it was important for parents to remain malaria-free so that they could take care of their children. Others believed younger children should be prioritized as they had lower immunity and were more susceptible to malaria.

Nets used for purposes other than malaria prevention

While none of the participants themselves mentioned using a net for a purpose other than putting it over their bed at night, participants mentioned that other people had used nets for other purposes, for example, to hold drying cassava, to use as a fishing net, or to serve as a pillow or blanket.

Participant Activity Patterns

Participants reported engaging in many routine activities during the night and early morning hours when *Anopheles* mosquitos are biting which precluded being protected under a bed net. These activities included leaving early in the morning to work in the hills, preparing dinner in the evening (some cooking outside, and others cooking inside), coming home from the market late, working as night security guards, fetching water, going out to bars, visiting friends, or children playing outside in the evening.

> *"I may have got it from the hills where I could walk daily during that period. There [is] some work we were doing in [the] hills, that required us to go very early and [sometimes] walking in the late-night hours; so that's where I could have [gotten mosquito bites], which caused that malaria. For instance, I could leave here very early in morning, and return about 23:00hrs at night. So, I could walk in various environments, and [sometimes] I could [get] [mosquito] bites; hence the reason for developing that malaria. And when I developed that malaria, I transmitted it to other family members; and soon most of them also suffered it." (IDI 1, Karongi)*

Discussion

Study participants were well aware that mosquitoes caused malaria, knew about or had directly experienced malaria symptoms, and knew why and how to use a bed net. The biggest barrier to using a net was lack of access to one. Other common reasons for not using a net include physical discomfort or concerns with the net chemicals, logistical challenges of hanging the net, or engaging in routine work or social activities during mosquito biting times.

Our study participants reported similar barriers and facilitators to using nets which have been reported elsewhere. Motivations to use nets include protecting against the nuisance of mosquitoes,[19,22,36,37] protecting against malaria, [18,22,36,38] mitigating the impact of cold weather,[18] and protecting them from items that could fall from the ceiling.[25] Barriers to using a net include not wanting to use nets once they believed chemicals had expired,[20,26] or experiencing skin irritation caused by the chemicals on the net.[20,26] Though prior studies have described lack of use because sleeping under the net was too hot,[19,22,36] participants in our study did not report this as a barrier and an earlier study in Rwanda found that use of bed nets occurs in spite of the heat as individuals have a high level of understanding about the risk of malaria.[25] Interestingly, whereas prior studies in Rwanda found that bed bugs were a major barrier to use and informed NMCP educational campaigns,[39] no one in our study mentioned bed bugs as a deterrent to bed net use.

Our study suggests there are several ways in which product design, education, and distribution could be improved to strengthen net access and use. In terms of product design, participants in this study preferred conical to rectangular nets. A study found that participants were 3.55 times more likely to use a net with a shape that they liked better compared to other net shapes (95% CI

2.98, 4.23).[40] It would make sense for the NMCP to make sure that conical nets are available, or to give participants a choice between conical nets and rectangular ones.

Though our participants understood that bed nets can help mitigate the risk of contracting malaria, more information about the chemically treated bed nets could help facilitate bed net use. For example, information about how long it takes for the chemicals in nets to expire, what to do with the nets when they have expired, information about how to handle nets when they are first received, and how to manage bed bugs if there is an infestation would be useful additional information to include in the communication materials. An experimental study on the impact of knowledge on consumer perceptions of chemicals in products revealed that those who were provided with information on toxicology were less afraid of chemicals in products compared to those who were given information about the use of chemicals in everyday products, or those who received education on a different topic.[41]

The Government of Rwanda's distribution system was meant to facilitate net access for all by facilitating free access for those in lower social economic status, specifically those in Ubudehe categories 1 (those who are unable to feed themselves without assistance) and category 2 (those who are able to accommodate themselves, though can only afford to feed themselves once or twice a day).[42] Citizens in category 3 (those who are employed or are employers of labor) and category 4 (those who are employed with businesses, industries, or are the leaders of companies) are expected to locate and pay for their nets outside of the government distribution system. However, our participants who did not receive a free net from the government reported challenges in finding them elsewhere, consistent with another Rwandan study[25] or reported being

unable to afford a net. The WHO recommends that governments distribute nets for free,[43] though there are differences in the research arena, with some articles finding that a market segmentation approach in which some socioeconomic categories would pay for nets is more effective,[44,45] while others claim that distributing nets for free is preferential.[46]

In addition to socioeconomic status as a barrier to receiving a net, other problems within the distribution process caused residents not to receive a net even when they were entitled to one. For instance, when residents were registered to receive a net in one district or village, and then moved to a new location, they were required to return to the location in which they had originally registered in order to receive a net from the government distribution. If bed net registration data were accessible on a national level, it would facilitate receiving a bed net if one moves to a new location.

Even among those whose households received a free net from the government, many reported not receiving enough nets for all household members. This is similar to other studies in Rwanda which reported some households receiving too many nets and others receiving too few.[20,26] Though the MOPDD has revised guidelines several times with the aim of increasing both bed net access and use[3] participants in the current study stated that access to nets continued to be a problem.

Similar to other studies in Rwanda, our participants reported that not all households who receive free nets use them for malaria control. Participants in this current study mentioned that others used nets for alternative purposes, though did not do so themselves. Some of the alternative uses

mentioned in the current study were drying cassava on the net, using it for fishing, or as a pillow or blanket. Prior studies have reported bed nets being used for multiple purposes other than protection from malaria,[25] including being used to dry foods, to fish, or for bed linens.[19,20] For example, some households opt to sell them rather than use them for mosquito protection in order to meet their cash needs for household necessities.[26]

Conclusion

Participants in this study were well aware that mosquitoes cause malaria and that bed nets can be used to prevent it; information and education were not reported as major barriers to net use. Rather, acquiring a net to use was reported as a major challenge. Strategies to increase bed net access include allowing all socioeconomic groups to be eligible to receive a net, and ensuring that there is one net distributed per sleeping space. The government net distribution program should be accompanied by routine monitoring to assess whether the system is being implemented as planned, and whether the system as implemented is leading to improved access. Government distributions should include both conical and rectangular nets as options to facilitate feasibility of hanging nets in and over different kinds of spaces. Finally, future studies could examine ways in which the chemicals used in bed nets could be altered so as to create fewer negative physical reactions to them among bed net users.

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Table 1: Number of KIIs and FGDs per district

District	Number of KIIs	Number of FGDs
Karongi	6	1
Nyamagabe	6	1
Ruhango	6	1

Table 2: Participant Demographics

Attribute	Number of Participants	
Gender	KII Participants: n = 18	FGD Participants n = 28
Male	7	12
Female	11	15
Age Groups		
20-29	0	2
30-39	6	13
40-49	4	6
50-59	5	6
60-69	2	1
70+	1	0

References

1. Fact sheet about Malaria. World Health Organization. Accessed December 5, 2020. https://www.who.int/news-room/fact-sheets/detail/malaria

2. Rwanda. Institute for Health Metrics and Evaluation. Published September 9, 2015. Accessed March 8, 2021. http://www.healthdata.org/rwanda

3. *U.S. President's Malaria Initiative Rwanda Malaria Operational Plan FY 2020*. U.S. President's Malaria Initiative; 2020. Accessed December 5, 2020. https://www.pmi.gov/docs/default-source/default-document-library/malaria-operational-plans/fy20/fy-2020-rwanda-malaria-operational-plan.pdf?sfvrsn=6

4. Center M and OPDD of the RB, Health M of, ICF. Rwanda Malaria Indicator Survey 2017. Published online July 1, 2018. Accessed March 8, 2021. https://dhsprogram.com/publications/publication-mis30-mis-final-reports.cfm

5. Malaria and Other Parasitic Diseases. Rwanda Biomedical Centre. Published January 9, 2020. Accessed December 5, 2020. https://rbc.gov.rw/index.php?id=671&L=0

6. Institute of Medicine (US) Committee on the Economics of Antimalarial Drugs. *Saving Lives, Buying Time: Economics of Malaria Drugs in an Age of Resistance*. (Arrow KJ, Panosian C, Gelband H, eds.). National Academies Press (US); 2004. Accessed December 5, 2020. http://www.ncbi.nlm.nih.gov/books/NBK215624/

7. Prevention C-C for DC and. CDC - Malaria - Malaria Worldwide - How Can Malaria Cases and Deaths Be Reduced? - Diagnosis and Treatment. Published January 28, 2019. Accessed April 25, 2021. https://www.cdc.gov/malaria/malaria_worldwide/reduction/dx_tx.html

8. Hanssen E, Goldie KN, Tilley L. Chapter 5 - Ultrastructure of the Asexual Blood Stages of Plasmodium falciparum. In: Müller-Reichert T, ed. *Methods in Cell Biology*. Vol 96. Electron Microscopy of Model Systems. Academic Press; 2010:93-116. doi:10.1016/S0091-679X(10)96005-6

9. What Is Malaria. Malaria No More. Accessed May 30, 2021. https://www.malarianomore.org/support/what-is-malaria/

10. Malaria - About Malaria - How to Reduce Malaria's Impact - Insecticide-Treated Bed Nets. Centers for Disease Control and Prevention. Published January 4, 2019. Accessed December 5, 2020. https://www.cdc.gov/malaria/malaria_worldwide/reduction/itn.html

11. Levitz L, Janko M, Mwandagalirwa K, et al. Effect of individual and community-level bed net usage on malaria prevalence among under-fives in the Democratic Republic of Congo. *Malar J*. 2018;17(1):39. doi:10.1186/s12936-018-2183-y

12. Yang G, Kim D, Pham A, Paul CJ. A Meta-Regression Analysis of the Effectiveness of Mosquito Nets for Malaria Control: The Value of Long-Lasting Insecticide Nets. *Int J Environ Res Public Health*. 2018;15(3):546. doi:10.3390/ijerph15030546

13. Ranson H, N'guessan R, Lines J, Moiroux N, Nkuni Z, Corbel V. Pyrethroid resistance in African anopheline mosquitoes: what are the implications for malaria control? *Trends Parasitol*. 2011;27(2):91-98. doi:10.1016/j.pt.2010.08.004

14. Tiono AB, Ouédraogo A, Ouattara D, et al. Efficacy of Olyset Duo, a bednet containing pyriproxyfen and permethrin, versus a permethrin-only net against clinical malaria in an area with highly pyrethroid-resistant vectors in rural Burkina Faso: a cluster-randomised controlled trial. *Lancet Lond Engl*. 2018;392(10147):569-580. doi:10.1016/S0140-6736(18)31711-2

15. Protopopoff N, Mosha JF, Lukole E, et al. Effectiveness of a long-lasting piperonyl butoxide-treated insecticidal net and indoor residual spray interventions, separately and together, against malaria transmitted by pyrethroid-resistant mosquitoes: a cluster, randomised controlled, two-by-two factorial design trial. *Lancet Lond Engl*. 2018;391(10130):1577-1588. doi:10.1016/S0140-6736(18)30427-6

16. Pulford J, Hetzel MW, Bryant M, Siba PM, Mueller I. Reported reasons for not using a mosquito net when one is available: a review of the published literature. *Malar J*. 2011;10:83-83. doi:10.1186/1475-2875-10-83

17. Alaii JA, Borne HWVD, Kachur SP, et al. Community Reactions to the Introduction of Permethrin-Treated Bed Nets for Malaria Control During a Randomized Controlled Trial in Western Kenya. *Am J Trop Med Hyg*. 2003;68(4_suppl):128-136. doi:10.4269/ajtmh.2003.68.128

18. Msellemu D, Shemdoe A, Makungu C, et al. The underlying reasons for very high levels of bed net use, and higher malaria infection prevalence among bed net users than non-users in the Tanzanian city of Dar es Salaam: a qualitative study. *Malar J*. 2017;16(1). doi:10.1186/s12936-017-2067-6

19. Lover AA, Sutton BA, Asy AJ, Wilder-Smith A. An exploratory study of treated-bed nets in Timor-Leste: patterns of intended and alternative usage. *Malar J*. 2011;10:199-199. doi:10.1186/1475-2875-10-199

20. Malede A, Aemero M, Gari SR, Kloos H, Alemu K. Barriers of persistent long-lasting insecticidal nets utilization in villages around Lake Tana, Northwest Ethiopia: a qualitative study. *BMC Public Health*. 2019;19(1):NA-NA. doi:10.1186/s12889-019-7692-2

21. Ng'ang'a PN, Jayasinghe G, Kimani V, et al. Bed net use and associated factors in a rice farming community in Central Kenya. *Malar J*. 2009;8(1):64-64. doi:10.1186/1475-2875-8-64

22. Manu G, Boamah-Kaali EA, Febir LG, Ayipah E, Owusu-Agyei S, Asante KP. Low Utilization of Insecticide-Treated Bed Net among Pregnant Women in the Middle Belt of Ghana. *Malar Res Treat*. Published online January 1, 2017. doi:10.1155/2017/7481210

23. Hlongwana KW, Mabaso ML, Kunene S, Govender D, Maharaj R. Community knowledge, attitudes and practices (KAP) on malaria in Swaziland: A country earmarked for malaria elimination. *Malar J*. 2009;8(1):29. doi:10.1186/1475-2875-8-29

24. Kateera F, Ingabire CM, Hakizimana E, et al. Long-lasting insecticidal net source, ownership and use in the context of universal coverage: a household survey in eastern Rwanda. *Malar J*. 2015;14(1). doi:10.1186/s12936-015-0915-9

25. Asingizwe D, Poortvliet PM, Koenraadt CJM, et al. Role of individual perceptions in the consistent use of malaria preventive measures: mixed methods evidence from rural Rwanda. *Malar J*. 2019;18(1):NA-NA. doi:10.1186/s12936-019-2904-x

26. Ingabire CM, Rulisa A, Kempen LV, et al. Factors impeding the acceptability and use of malaria preventive measures: implications for malaria elimination in eastern Rwanda. *Malar J*. 2015;14(1). doi:10.1186/s12936-015-0659-6

27. Baume CA, Franca-Koh AC. Predictors of mosquito net use in Ghana. *Malar J*. 2011;10(1):265. doi:10.1186/1475-2875-10-265

28. Moon TD, Hayes CB, Blevins M, et al. Factors associated with the use of mosquito bed nets: results from two cross-sectional household surveys in Zambézia Province, Mozambique. *Malar J*. 2016;15(1):196. doi:10.1186/s12936-016-1250-5

29. Ranasinghe S, Ansumana R, Bockarie AS, et al. Child bed net use before, during, and after a bed net distribution campaign in Bo, Sierra Leone. *Malar J*. 2015;14(453). doi:10.1186/s12936-015-0990-y

30. Andinda M, Mulogo E, Turyakira E& B. Predictors of sleeping under cost-free mosquito bed nets among children under-five years in Mbarara, Uganda: a household survey. *Afr Health Sci*. 19(1):1353-1360. Accessed June 15, 2021. http://www.bioline.org.br/abstract?hs19006

31. Nuwaha F. Factors influencing the use of bed nets in Mbarara municipality of Uganda. *Am J Trop Med Hyg*. 2001;65(6):877-882. doi:10.4269/ajtmh.2001.65.877

32. Sena LD, Deressa WA, Ali AA. Predictors of long-lasting insecticide-treated bed net ownership and utilization: evidence from community-based cross-sectional comparative study, Southwest Ethiopia. *Malar J*. 2013;12(1). Accessed June 15, 2021. http://link.gale.com/apps/doc/A534653606/AONE?sid=bookmark-AONE&xid=21193766

33. France EF, Wells M, Lang H, Williams B. Why, when and how to update a meta-ethnography qualitative synthesis. *Syst Rev*. 2016;5(1):44. doi:10.1186/s13643-016-0218-4

34. Interceptor G2 - the second-generation net to congrol insecticide resistant mosquitoes (Product Brochure). Published online 2017. Accessed June 12, 2021. https://agriculture.basf.com/global/en/business-areas/public-health/products/interceptor-g2.html

35. Royal Guard. Disease Control Technologies, Long Lasting Insecticide Treated Bed Net Manufacturer. Accessed June 12, 2021. http://www.diseasecontroltechnologies.com/royal-guard-1

36. Frey C, Traoré C, De Allegri M, Kouyaté B, Müller O. Compliance of young children with ITN protection in rural Burkina Faso. *Malar J*. 2006;5(1):70. doi:10.1186/1475-2875-5-70

37. Das ML, Singh SP, Vanlerberghe V, et al. Population Preference of Net Texture prior to Bed Net Trial in Kala-Azar–Endemic Areas. *PLoS Negl Trop Dis*. 2007;1(3):e100. doi:10.1371/journal.pntd.0000100

38. Koenker HM, Loll D, Rweyemamu D, Ali AS. A good night's sleep and the habit of net use: perceptions of risk and reasons for bed net use in Bukoba and Zanzibar. *Malar J*. 2013;12(1). doi:10.1186/1475-2875-12-203

39. Abejirinde I-OO, Ingabire CM, Vugt M van, Mutesa L, Borne B van den, Busari JO. Qualitative analysis of the health system effects of a community-based malaria elimination program in Rwanda. *Res Rep Trop Med*. 2018;9:63-76. doi:10.2147/RRTM.S158131

40. Mategula D, Ndeketa L, Gichuki J, Zimba B, Ching'ani W, Chipeta MG. Effect of bed net colour and shape preferences on bed net usage: a secondary data analysis of the 2017 Malawi Malaria Indicator Survey. *Malar J*. 2020;19(1):428. doi:10.1186/s12936-020-03499-9

41. Saleh R, Bearth A, Siegrist M. Addressing Chemophobia: Informational versus affect-based approaches. *Food Chem Toxicol*. 2020;140:111390. doi:10.1016/j.fct.2020.111390

42. Ezeanya-Esiobu C. *The Rise of Homegrown Ideas and Grassroots Voices: New Directions in Social Policy in Rwanda*. UNRISD Working Paper; 2017. Accessed April 11, 2021. https://www.econstor.eu/handle/10419/186097

43. WHO Guidelines for malaria. Accessed June 22, 2021. https://www.who.int/publications/i/item/guidelines-for-malaria

44. Alfonso YN, Lynch M, Mensah E, Piccinini D, Bishai D. Willingness-to-pay for long-lasting insecticide-treated bed nets: a discrete choice experiment with real payment in Ghana. *Malar J*. 2020;19(1):14. doi:10.1186/s12936-019-3082-6

45. Moscibrodzki P, Dobelle M, Stone J, Kalumuna C, Chiu Y-HM, Hennig N. Free versus purchased mosquito net ownership and use in Budondo sub-county, Uganda. *Malar J*. 2018;17:363. doi:10.1186/s12936-018-2515-y

46. Cohen J, Dupas P. Free Distribution or Cost-Sharing? Evidence from a Randomized Malaria Prevention Experiment. *Q J Econ*. 2010;125(1):1-45. Accessed June 22, 2021. http://www.jstor.org/stable/40506276