Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Factors influencing insecticide-treated net access and use in Papua New Guinea: a mixed-methods investigation

Beatrice R Egid

beatrice.r.egid@gmail.com

Independent Researcher

John Bosco Keven

Papua New Guinea Institute of Medical Research

John Cowan

Papua New Guinea Institute of Medical Research

Clara Are

Papua New Guinea Institute of Medical Research

Christine Pombreaw

Papua New Guinea Institute of Medical Research

Micah Muri

Papua New Guinea Institute of Medical Research

Celine Figa

Papua New Guinea Institute of Medical Research

Melanie Koinari

James Cook University

Rachael Farquhar

Burnet Institute

Zebedee Kerry

Papua New Guinea Institute of Medical Research

Maria Ome-Kaius

Papua New Guinea Institute of Medical Research

Moses Laman

Papua New Guinea Institute of Medical Research

Leanne J Robinson

Papua New Guinea Institute of Medical Research

Stephan Karl

Papua New Guinea Institute of Medical Research

Research Article

Keywords:

Posted Date: April 19th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-8945689/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Abstract

Background

Malaria is increasing in Papua New Guinea (PNG) and there is a need to better understand the reasons for sustained high transmission. People's perceptions and behaviours around insecticide-treated nets (ITNs) are critical in determining their overall effectiveness.

Methods

This study employed a mixed-methods design, integrating qualitative data from focus group discussions and participatory activities with quantitative data from household surveys, to explore and contextualise perceptions and end-user behaviours around ITNs in PNG. Data was collected in 17 villages across 6 provinces.

Results

Key themes explored included ITN distribution and coverage, usage patterns, and user preferences. Most people acquire ITNs via mass distribution campaigns (71%), and there is a reluctance to pay for nets as well as concerns around the quality of store-bought nets. Providing ITNs only to 'at risk' groups through continuous distribution channels may forego opportunities to close coverage gaps. The proportion of households with at least one ITN was high in all provinces (88.4–97.4%), and while universal coverage was observed in 61% of households, many participants felt that an inadequate number of ITNs were available for the number of people per household. Community members highlighted the need for better education and awareness-raising around ITN handling, maintenance and replacement during and after distribution. Gender and age influenced decision-making around net sharing, while several factors demotivated people from using ITNs, including the perception that they to make it too hot while resting, cause skin irritation and attract bed bugs. Community members preferred ITNs made of soft, flexible, lightweight polyester, as opposed to ITNs made of more durable but tougher polyethylene.

Conclusions

The findings from this study elucidate factors determining ITN access and use in PNG and can provide guidance to refine programs to increase reach and effectiveness of ITN-based interventions in PNG and elsewhere.

Background

Malaria is a major public health concern in Papua New Guinea (PNG), with an estimated 1.5 million cases in 2023, accounting for >85% of all cases and >90% of all deaths in the WHO Western Pacific

region (1). ITNs are the cornerstone of malaria control in PNG, distributed primarily through mass campaigns every three years and complemented by continuous distribution channels, where additional nets are distributed to 'at risk' groups primarily at health facilities (2). Community volunteers are recruited to perform critical tasks during mass distribution, such as collecting data for the census to determine the number of ITNs required and assisting during distribution. ITNs are distributed according to a distribution key that results in approximately one ITN for every 2 household members.

While the country-wide mass distribution of insecticide-treated nets (ITNs) initially coincided with a considerable reduction of malaria incidence between 2009 and 2014, cases across PNG continuously increased again between 2015-2023 (3). Several factors are likely to have contributed to this resurgence. Firstly, PNG has faced challenges with low insecticidal efficacy ITNs since 2013. While ITNs distributed within PNG were exclusively deltamethrin-treated PermaNet 2.0® between 2006 and 2019, evidence shows that between 2013 and 2019 these ITNs exhibited severely reduced insecticidal efficacy due to changes to the manufacturing process (4, 5). In addition, suboptimal ITN coverage and changes in end-user behaviour, leading to decreased ITN usage, may also be impacting ITN effectiveness and contribute to the increase observed in malaria rates.

While surveys have reported sustained high usage rates of ITNs in several PNG provinces (6, 7), other areas, such as the PNG Islands and Highland Regions, consistently report lower ITN usage rates (7). For example, a study conducted in New Ireland Province highlighted how ITN coverage and use were very low two years after distribution, when only 9% of households had universal ITN coverage (at least one ITN for every two people) and only 14% of participants reported having slept under a net the previous night (8). Concerningly, data from PNG malaria indicator surveys conducted every 3 years suggest that ITN coverage and use are gradually decreasing, with the average percentage of the population with access to an ITN dropping from 67% in 2017 to 49% in 2023 (7, 9).

Social and cultural factors interplay with the epidemiology of malaria [10], and in PNG there is significant within-country heterogeneity in malaria transmission as well as high cultural diversity (10-12). The majority of human-vector contact in PNG occurs outside the home, due to the local *Anopheles* vectors preferentially biting outdoors and a large part of social life taking place outdoors in PNG communities (13, 14). Critically, people in rural PNG spend a substantial amount of time outdoors or in semi-open (i.e., roof-only) structures between 4pm and 8am, when *Anopheles* mosquitoes are active [6]. During this period people conduct activities such as socialising, household chores (cooking, washing laundry and dishes etc.), bathing, swimming, fishing, hunting and gardening, leaving them frequently unprotected by ITNs (6).

In addition, ITN non-use in the population may be driven by a range of interrelated human, net and environmental factors such as heat, perceived (low) mosquito density and living/sleeping space restrictions. Previous studies have attributed low net use to a general 'attitudinal context' of indifference, rooted in a lack of fear of malaria infection (15). Reviews of reasons for non-use of nets in malaria

endemic regions across the globe frequently report low perceived risk and heat as prominent contributing factors (16, 17).

Despite ITNs having been distributed at country scale since 2009, there have been few studies in recent years exploring reasons for net non-use in PNG, none of which have specifically explored community perceptions around ITN distribution processes, coverage levels and preferences for specific products (18).

This study aims to further investigate factors that may undermine ITN effectiveness in PNG, exploring and contextualising perceptions and end-user behaviours around ITNs. These insights can support the PNG National Malaria Control Program in making informed ITN procurement decisions to select the best possible ITN products and refine aspects of the ITN distribution strategy.

Materials and Methods

Study design and locations

A mixed-methods design was used to investigate perceptions and end-user behaviours around ITNs in PNG. The qualitative component included focus group discussions (FGDs) and a participatory, human-centred design activity where community members interacted with different ITN products and shared their perspectives. The quantitative component involved a household survey.

The study locations were selected in consultation with Provincial Health Authorities and the PNG National Malaria Control Program. Selection considered factors such as the timing of ITN distributions, the distributed ITN products, security, accessibility, population size and malaria burden. Study sites covered a range of geographical and sociocultural settings (North Coast, South Coast, Islands, Highlands) in PNG, known to differ in terms of attitudes and behaviours around ITNs [11].

For the qualitative study, data collection was conducted in six villages across four provinces - Madang Province, New Ireland Province, Central Province and Jiwaka Province. The quantitative household survey was conducted in twelve villages across three provinces – Madang Province, East Sepik Province, and Sandaun Province. These study locations were primarily selected to align with the rolling national ITN distribution schedule, such that they could be surveyed at the same time after ITN distribution (3 years). Study locations are shown in Fig 1.

Data collection

Qualitative component

For the FGDs, an interview guide was developed based on the following thematic areas: (1) malaria knowledge, (2) ITN behaviours, (3) ITN acceptability and preferences (4) ITN community awareness (S1 File). For the human-centred design activity, participants were invited to interact with seven different ITN

products available in PNG (SafeNet ®, Yorkool G1 ®, Yahe ®, Royal Sentry 2.0 ®, Interceptor G2 ®, MAGNet ® and DuraNet ®, summarised in Table 1) to reflect on their size, material, colour and other design features, in order to generate an understanding of community preferences for various ITN characteristics. Data collection tools were piloted in two villages in Madang province and refined for use in other study sites – pilot data was also included in the final analysis.

Table 1. ITN products and properties included in human-centred design activity.

Net product	Colour	Material[a]	Active ingredient	Prequalification details
SafeNet ®	Green	PE	Alphacypermethrin	https://extranet.who.int/prequal/vector-control-products/safenet
Yorkool G1 ®	Light yellow	PE	Deltamethrin	https://extranet.who.int/prequal/vector-control-products/yorkool-g1-ln
Yahe ®	Yellow	PE	Deltamethrin	https://extranet.who.int/prequal/vector-control-products/yahe-ln
Interceptor G2 ®	Light blue	PET	Alphacypermethrin/ Chlorfenapyr	https://extranet.who.int/prequal/vector-control-products/royal-sentry-20
Royal Sentry 2.0 ®	Light green	PET	Alphacypermethrin	https://extranet.who.int/prequal/vector-control-products/interceptor-g2
MAGNet ®	Blue	PET	Alphacypermethrin	https://extranet.who.int/prequal/vector-control-products/magnet
DuraNet LN ®	Light blue	PET	Alphacypermethrin	https://extranet.who.int/prequal/vector-control-products/duranet-ln

[a]Note: PE – polyester/multifilament, PET – polyethylene/monofilament

Between July 2024 and December 2024, convenience sampling was used to recruit community members for the FGDs, and discussion groups were stratified by gender and age to maximise participation from community members of different demographics. All FGDs were conducted in PNG Tok Pisin by Papua New Guinean qualitative researchers. Prior to enrolment, the research team engaged with community leaders and community health workers in each community and briefed them about the study, which guided selection of potential participants. Written informed consent was provided by all participants. Overall, 22 FGDs were conducted with a total of 226 participants (127 men, 99 women).

All FGDs were audio recorded using a digital audio recorder, and at the end of each day recordings were backed up onto a computer and uploaded onto a shared drive. The data collection team also wrote field notes after each FGD, detailing their thoughts on the dynamics observed during the FGDs and themes that were emerging from the discussions. Recordings were transcribed verbatim in Tok Pisin, then translated into English.

Quantitative component

For the household survey, a total of 714 households (approximately 60 per village) were surveyed between September 2023 and February 2024, approximately 3 years after the last ITN mass distribution and before the next distribution. The research team visited each household and, where written informed consent was given, conducted the survey with the householders identifying as household heads, or another adult with authority in the household. All ITNs present in household were inspected and matched to their users. Demographic details on all persons living in survey households were also collected. Overall, the 714 households comprised of 4073 people and contained 1988 ITNs.

Data analysis

For the qualitative component, English translations of the transcripts were used to conduct a thematic analysis of the data, following a six-stage process which included (1) familiarisation with the data, (2) generating initial codes, (3) searching for themes, (4) reviewing themes, (5) defining themes and (6) writing up [20]. A coding framework – an organised system for categorising and interpreting collected data (S2 File) - was developed through a mixed deductive and inductive approach, based on the study objectives and incorporating other themes arising in the data. This framework was used to code the transcripts line-by-line in Nvivo 14 software, categorising the data into groups with similar content/concepts. Data under each code was analysed, interpreted and synthesised to generate themes which answered the research aim. Field notes and discussions within the research were used to support and refine the analysis.

For the quantitative component, descriptive analysis was undertaken. This included analyses of proportions of the frequency of observations and participant responses. When appropriate, statistical tests to compare two proportions were conducted, and 95% confidence intervals of proportions were calculated.

Findings from the qualitative and quantitative components were then compared to highlight coherences and discrepancies between the two data sets, and to develop explanatory insights into factors influencing ITN effectiveness in PNG.

Research team and reflexivity statement

Authors for the qualitative study had diverse backgrounds and research experiences. Data collection was conducted by JC and CA, researchers from PNG with several years of experience conducting qualitative and participatory research with communities in PNG. Data analysis was conducted collaboratively by JC and BRE, a researcher from the UK with a background in vector-borne disease and participatory research approaches. ZK and RF, qualitative researchers with expertise in malaria from PNG and Australia, respectively, contributed to the design of the research tools and analysis of the data.

SK and JBK, quantitative vector-borne disease researchers from Australia and PNG, respectively, also contributed to research tool design.

Results

In the following sections, study results are presented under three main themes: Distribution and coverage, Usage patterns, and ITN preferences.

Distribution and coverage

Sources of ITNs

In the qualitative study, many participants reported having received their ITNs from Rotarians Against Malaria (RAM), the implementing partner of the PNG National Department of Health (NDOH) which coordinates the mass distributions of ITNs in PNG.

This was confirmed by the household survey, where 71.4% of N=1988 ITNs in N=714 surveyed households had originated through the triennial mass distributions (Table 1). Several community members described how, even if their nets became damaged in the intervening period between distributions, they would wait for the next round of ITN mass distribution instead of replacing through another channel:

When they gave [nets] to us, we used them for a while, but now they're damaged … We don't think about getting replacements … We just wait for the distribution, we don't replace them or buy new ones. (youth, female, Central Province)

Household survey results indicated that community members acquired another 10% of ITNs through the continuous distribution mechanisms set up by PNG NDOH and RAM, primarily at antenatal clinics, while other minor sources of ITNs included NGOs, local shops and relatives (Table 1).

Table 1. Sources of ITNs in PNG determined by the household survey.

Source	Number of ITNs	%
Government mass distribution	1420	71.4
Government continuous distribution	200	10.1
Shops (private procurement)	151	7.6
Relatives	61	3.1
Other organisation (e.g. NGO, Church)	37	1.9
Unknown	119	6.0
Total	**1988**	**100.0**

Qualitative findings also reflected this, with some community members reporting purchasing additional nets from stores frequently referred to as “Chinese” or “Asian” stores, despite the perception that these nets may be untreated or of lower quality than distributed ITNs. Participants generally disliked having to spend their own money on nets, cited to be purchasable on the market for 2-10 PNG Kina (approximately US$ 0.5-2.5).

Others with money go and buy nets from the store. I’ve heard about this, but I’m not sure if the nets sold in stores are treated with the same insecticide as the ones distributed. (adult, male, Madang Province)

We need mosquito nets, and sometimes they don't give them to us properly. I am a woman who must talk a lot when there are not enough mosquito nets. I use my own money to buy them for my family; that's a concern I have. (adult, female, Jiwaka Province)

The qualitative findings suggest that while some community members asked for additional ITNs from hospitals or healthcare centres, only specific groups (for example pregnant women, prisoners, boarding school students) were given nets for free. This is in-line with the distribution strategy, where continuous distribution mechanisms target specific priority groups (2).

Some pregnant mothers go to the clinic, and they give them mosquito nets, and they bring them back. They take them home, and sometimes there are leftovers. (adult, female, Jiwaka Province)

The last time, we went [to the hospital] because Dad was sick. We went to the hospital to ask them to give us some mosquito nets, but for me, they didn’t give any mosquito nets. They just gave an injection and some supplies for him, that’s all. (youth, female, Central Province)

Community members also mentioned cases where health care workers and/or community volunteers stockpiled ITNs to sell on for profit. This was raised as an issue across all provinces but cited as a particular problem in Jiwaka province; one participant described an instance where community members were told to pay for ITNs that should have been distributed for free as part of the normal mass distribution campaign.

When they give out mosquito nets, they take names and say that you have to pay 1 Kina for the net. If you don't pay 1 Kina, they won't give you a net, and you have to come back and buy it. (youth, female, Jiwaka Province)

The people at the hospital appointed volunteers within the community to distribute the nets. However, these volunteers did not distribute the nets properly. They kept some of the nets, that's why some families received only a few nets or just one. (youth, male, New Ireland Province)

Individual and household coverage

The household survey indicated that the surveyed communities had adequate access to ITNs. Of the n=714 surveyed households, 88-98%, depending on province, had at least one ITN 3 years post distribution (confirmed through inspection of ITNs). At the same time, the average number of ITNs per household among provinces ranged from 2.8 – 3.4. This translated into an average of 0.5-0.6 ITNs per person with 5-95% centiles of 0.13 to 1.2 ITNs per person. Universal coverage was observed in 61% of survey households and was higher in households with lower number of people, such that 74% of household with 1-4 members, 55% with 5-9 members and 30% with 10 or more members were observed to have 2 ITNs per person, respectively. Overall, 82.9% (n=3365/4061) of household members were reported as having used an ITN the previous night.

The qualitative findings show that while community members agreed that household coverage was generally high, many felt that an inadequate number of ITNs were distributed for the number of people in each household. Participants frequently expressed dislike at having to share ITNs with other family members, and perceived that the shortages were due to supply issues or challenges with the ITN distribution process.

Maybe they didn't bring enough for the whole population, so they have to distribute a small amount. That's why they said that one net should be shared by two people. But I'll be honest with you, I hate sleeping with two or three people inside a mosquito net… (adult, male, Central Province)

In areas where net shortages were particularly severe, there were reports of community members fighting over limited numbers of ITNs.

They say the mosquito nets are provided for us, but they also say there aren't many … It's difficult, and people rush, with some getting nets and others not … You can imagine the fights over getting mosquito nets, and malaria becomes like a conflict. It's normal for us to rush, and each family gets one mosquito net. (adult, male, Jiwaka Province)

ITN manufacturing dates recorded in the household survey indicated that people continue to use ITNs from previous rounds of mass distribution and only gradually replace them with fresh campaign nets. As such, from the ITNs with available manufacturing year data (n= 1507/1988; 75.8%), 30% (n=452/1507) ITNs were manufactured in 2017 or before, indicating that they had not been distributed in the 2020

distributions that preceded the present study, but in previous distributions, and that many of them were 6 or more years in use.

Findings from the qualitative study shed light on some of the potential reasons for this – some community members kept newly distributed nets in storage for visitors, while there was also an emphasis in many communities on continuing to fix and use older nets until they became significantly damaged.

I like this net [SafeNet ®] … I use them as a standby, any visitor that visits can use these mosquito nets. They don't use it with the family. The visitors that come, we leave two mosquito nets each for them to use. (adult, male, Madang Province)

I have extra mosquito nets because we have visitors coming, like relatives, so we save these for the relatives who come to stay with us, and we give them to sleep under. (adult, male, Madang Province)

Corroborating this, the household survey indicated that 21% (n=48/254) of all unused ITNs at the time of the survey were considered as reserved for later use or for guests.

Community volunteers

While community volunteers act as a key interface between the ITN distribution programme and communities, participants in the qualitative study highlighted several challenges to this model. Some study participants who had acted as community volunteers reported that they received limited training on the processes behind ITN distribution, for example what information to share with community members and how to discuss the rationale around the number of ITNs distributed to each household. This sometimes created conflict, as volunteers were held accountable by their communities for ITN shortages, as illustrated by the following statements made by men who had acted as community volunteers:

We follow the numbers provided in those forms and distribute the mosquito nets accordingly ... it might seem like a family should get six, seven, or eight nets based on our counting. But then, later on, we see that no, the numbers we counted might be reduced ... many times people in the community come back upset with us, the volunteers, and we explain, 'No, this work was done up there and then brought down, so we are just following instructions.' (adult, male, Madang Province)

Another complaint is that there are many people living in one house … there are so many people in one house, and then they're given only three or four nets, it's not enough. They ask for extras, but we can't give them. (youth, male, Jiwaka Province)

There were even some reports of violence towards community volunteers, which arose when people became angry because of the perceived deficit in ITNs.

Now, some people did not receive mosquito nets … so they beat the volunteer who was distributing the nets. In our area, the boys beat a volunteer. I don't know if it was because they didn't get the nets or because they were left out. (youth, male, New Ireland Province)

Education and awareness

Many community members felt that they were given inadequate information on how to handle the nets before use, how to maintain their nets, and how often to expect the nets to be replaced.

No such instructions were given to us, they just come give, give, give and leave because they wanted to get paid. Many of them [net distribution team] focused on complaining over pay during this time of mosquito net distribution … They talk a lot but don't focus on us. (adult, male, Madang Province)

Participants were also dissatisfied with the lack of follow up support after net distribution, highlighting their desire to share their concerns and seek advice about side effects that arose from net usage.

There have been instances where they showed us how to wash and use the nets, but they only came briefly and didn't follow up. They left us to figure it out on our own. So, if any issues or harm come up, we don't have a way to report it or understand the root cause. ... They should ensure these workers are well-trained and capable in the field. If this happens, questions and issues raised during such activities will be addressed properly, making it easier for us to express ourselves and share our concerns. (adult, male, Madang Province)

Some of these shortfalls in community education were also evident in the household survey. For example, 70% of all household heads (n=496/714) indicated that they did not know that ITNs should not be exposed to the sun after washing as this may decrease their insecticidal efficacy. This proportion was similar for male and female household heads.

Usage patterns

Gender and age-related factors

Age and gender both had a significant influence on decision-making around how nets were shared within households. In the FGDs, many community members highlighted how men would sleep outside while prioritising indoor net use for the women and children in their families, in line with cultural expectations that fathers should protect their families. Children and the elderly were also often seen as priority groups who were given preference for sleeping under ITNs.

I always prioritize my wife and the young children. I sleep outside without protection. Because of this, I've contracted malaria. I think of their safety and not of mine … When we're short on nets, I choose to let the mother and kids use them, and I sleep unprotected. (adult, male, Madang Province)

I see that many of us can't fit inside them [nets], and the first thing I think of is the elderly ... I also take care of some children whose parents are not around. So, I give the nets to the elderly and the children. My husband and I sleep without nets, that's how it is. (adult, female, Jiwaka Province)

Community members highlighted how ITN distribution processes showed limited consideration of household structure, composition and family dynamics. For example, it was deemed important that adolescents had their own nets, in respect of their privacy. However, participants reported that adolescents were sometimes considered as 'children' during ITN censuses, and due to resulting insufficient net numbers they often had to sleep with their parents or would choose to sleep outside. While ITN sharing was usually negotiated well within families, tensions sometimes arose.

I believe everyone is entitled to a mosquito net, but it should be allocated based on age and household structure. For instance, I have five grandchildren living with me. The ones from the same parents share one mosquito net, while the others share another. My husband and I use one for ourselves. For someone like my son, who is single and already nearing 30 years old, he should have his own mosquito net. (adult, female, Central Province)

But now, when we talk about families in one house, it's not good if older children are sleeping with their parents. For smaller children, yes, they can fit under one net, but for older children, 18 and above, they'll have to sleep separately. (adult, male, Madang Province)

These issues may arise from the distribution key that is used to calculate ITN needs. The distribution key states that i) one net for a mother and father and up to two children under the age of six; ii) one net for every three boys; and iii) one net for every three girls will be provided. Adult children, while frequently part of their parents' household, are not appropriately considered. It is hard to imagine how 3 adolescent or adult 'boys' or 'girls' would comfortably share a net.

For females, reported ITN use was slightly higher at 85.5% (1773/2074) versus 80.3% (1584/1977) for males. The ITN use ratio was 0.94 males to 1 female, reflecting slightly lower usage by males overall, and supporting the insight from the FGDs that men would sometimes sleep without a net to enable their families to use them, or reluctance to share an ITN with other family members.

However, there was also a statistically significantly higher proportion of single male ITN users (31.0%, n=469/1584) compared to female users (15.2% n=269/1773, $p<0.001$). This may be because mothers share ITNs more frequently with younger children. As shown in Fig 2, children under 10 nearly always share ITNs. Adolescents up to age 20 increasingly use one ITN per person, as reflected in the qualitative findings which highlight the social importance of adolescents being able to sleep alone under a net. This trend continues into adulthood for males, with about 40% single use in the 20-49 years age groups which then increases for men over 50. In contrast, less than 15% of the women between 20 and 49 use one ITN per person. For older women, the percentage of single ITN users was similar that of older men.

Reasons for not sleeping under an ITN

When prompted to identify the main reasons for not sleeping under an ITN in the household survey, participant responses included that the ITNs were too hot (37.1 % of responses), caused skin irritation (13.4%%), were too much work (7.3%), aggravated nuisance from bed bugs (6.3%) or were not useful (0.8%). A large proportion of responses (35.1%) alluded to 'other reasons'.

When further asked to specify some of the other reasons the predominant answers were about health concerns (asthma etc.), seasonal use of ITNs, concerns about physical damage and insecticidal efficacy, the need to share and lack of access to nets and the perceptions that ITNs were not needed.

Many of these reasons were echoed in the qualitative findings, for example community members spoke about itching, rashes and facial swelling that arose after sleeping under an ITN. Children, the elderly and asthmatic people were thought to be particularly sensitive to the strong chemical smell of new ITNs, with some participants suggesting that individuals in these groups should not sleep under an ITN.

I feel extremely hot and at the same time, I feel like my face is salty or something, like there's salt on it … I don't really like the feeling when I sleep at night, I don't want to sleep inside the mosquito net so I lift the mosquito net up. (youth, female, Madang Province)

These mosquito nets are not good for people with asthma. The chemicals used to treat the nets can be very dangerous for people with asthma … They should not sleep under treated mosquito nets. (adult, male, Central Province)

While only 6.3% of participants in the household survey highlighted bed bugs as their primary reason for not using nets, a large proportion (73.8%) of heads of infested households reported that the bed bug infestation problem arose or intensified following the mass distribution of ITNs, whereas only 16.8% reported it as a pre-existing problem before ITN distribution.

This was reflected in the qualitative study, most significantly in Madang province. Many community members were concerned that recently distributed ITNs were ineffective at killing bed bugs, while others believed that ITNs had introduced or exacerbated bed bug infestations in their homes. Some community members frequently washed their nets to try to get rid of bed bugs, believing that they were attracted to dirt, a practice likely to have a detrimental effect on ITN efficacy. There were additional concerns that bed bugs themselves could cause diseases such as scabies, which contributed to the decision of some community members not to use ITNs.

A few years ago, when they distributed mosquito nets, we didn't experience this [bed bugs]. Last year, it's true that when they distributed the nets, bed bugs started coming. It's not just us - the whole community experienced this. Maybe they used some kind of chemical that attracts bed bugs to these types of mosquito nets. (adult, female, Madang Province)

When bed bugs come in, it's because of dirt. The dirt attracts the bed bugs. The net sometimes gets dirty if it's not washed, and then bed bugs come inside … If we wash the nets and bed sheets, it will be fine. The bed bugs won't come. (adult, male, Madang Province)

Additional factors that deterred people from sleeping under an ITN also emerged in the qualitative findings. For example, some men from the Central Province didn't use an ITN while at home because of space restrictions, but used them when they were camping outside in the bush where they felt exposure to mosquitoes was more intense:

We hardly used mosquito nets in the house because of the spacing. Most of the mosquito nets we use are when we are out in the garden place or bush, or when we are out fishing. That's when we carry the mosquito net use it (adult, male, Central Province)

There were also several community members who would only use ITNs in the rainy season when mosquito density was perceived to be higher. Many participants stored their ITNs away during the dry season and set them up again when they observed mosquito numbers rising. Others described how they preferred not to use nets on particularly hot evenings.

We don't use mosquito nets often; it's more of a seasonal thing. When it's mosquito season, most of us start using mosquito nets … However, during times when we don't have mosquito nets or when it feels too hot inside our homes, we don't sleep under them. It really depends on personal preference. If someone wants to use a mosquito net, they can go ahead and set it up, but if they don't, no one forces them to use it. (adult, female, Central Province)

Low net use was also linked with certain events and situations. For example, men often described how they preferred to sleep outside, rather than under a net, when returning home after drinking alcohol. Furthermore, community members described how big gatherings such as funerals often happened at night, after which people would not feel motivated to use an ITN.

It's like, sometimes when we come back drunk, we don't sleep under the nets—we just come and lie down outside and sleep. (youth, male, Madang Province)

Big gatherings sometimes happen, or someone passes away, and there are big gatherings at night. We go there, and when we get sleepy or tired, we don't really think much about the mosquito net. We just fall asleep anywhere, like on the floor of the house or on a bed. (youth, male, Madang Province)

Alternative use of ITNs

All participants of the household survey reported awareness of some form of alternative ITN use besides protection from mosquitoes, and a total of 1095 responses identifying alternative uses were received (multiple responses per household possible). The predominant response was use of ITNs as fishing nets (n=456, 41.1%), followed by use for covering plants in nurseries (n=142, 12.9%), bed sheets, covers or pillows (n=33, 3.0%), and as bags or to make rope (n=14, 1.3%).

A total of 456 responses indicated 'other' repurposing options, revealing the frequent usage for washing and straining sago and kambang (an ingredient for betel nut chewing), killing lobsters and prawns by

making use of the highly lethal action of insecticides against aquatic life, and as chicken fencing. Less frequent responses were hammocks and swings for children, and window or door screens.

The qualitative study highlighted how ITNs were often used for alternative purposes when they became damaged and unusable as bed nets – this included using the nets as fly wire on windows, fencing for gardens, shelter for plant nurseries, strainers for coffee grinds and to cover utensils.

I don't know if it's the insecticide they sprayed on it or how they made it, but the net is hot, and we don't use it anymore to keep mosquitoes away. We don't sleep inside it ... It's good for closing windows, so we've now cut it and used it for the windows again. (youth, male, New Ireland Province)

ITN preferences

In the participatory activity conducted as part of the qualitative study, participants interacted with and shared their perceptions of seven ITN products (overview in Table 2).

Table 2. Overview of perceptions towards seven net products explored in human-centred design participatory activity.

Net product	Positive attributes	Negative attributes
SafeNet ®	• Soft and breathable • Easy to tuck under mattress and stays securely in place • Light in colour • Spacious and comfortable for use in different seasons	• Not very durable • Tears easily • Attracts bed bugs
Yorkool G1 LN ®	• Flexible and stays securely in place • Doesn’t scratch or irritate the skin • Small holes prevent mosquito, insect, bed bug entry • Spacious	• Attracts bed bugs
Yahe ®	• Lightweight and cool • Small holes prevent mosquito, insect, bed bug entry • Flexible, accommodates people of different sizes • Easy to fix when damaged	• Attracts bed bugs
Interceptor ® G2	• Stylish appearance • Smooth material • Flexible, hangs well around the bed	• Causes itchiness • Attracts bed bugs • Hot to sleep under
Royal Sentry ® 2.0	• Soft • Strong, resists damage	• Attracts bed bugs
MAGNet ®	• Strong and durable, lasts for a long time without damage	• Thick ‘string’ material is inflexible • Difficult to set up and rolls back up when not secured • Sticks to the skin • Hot to sleep under
DuraNet ®	• Strong and durable, lasts for a long time without damage	• Attracts bed bugs • Thick ‘string’ material scratches the skin • Rolls up easily and doesn’t stay in place • Causes skin irritation • Causes side effects such as coughing

Material type and colour

Material type was the most influential factor in determining community members' preferences for different net products. Across the provinces, people generally preferred ITNs made of softer, lighter polyester materials such as SafeNet ®, Yorkool G1 ® and Yahe ®. These nets were perceived to be easier to hang up, stayed in place well while people slept inside, and let more airflow through which meant they were cooler.

I like the Yorkool net because it's a really nice net and it's not too strong. When I sleep inside it doesn't fold and I can sleep well. When I have a sore on my feet, when it comes in contact with the net it doesn't scratch it. (adult, male, Madang Province)

ITNs made of tougher materials, such as DuraNet ® and MAGNet ® (both made of high-density polyethylene) were less preferred - community members disliked the string-like fabric which could stick to, scratch or irritate the skin. Several community members described how these nets would roll up in an irritating way when dislodged during the night (a particular issue when nets were shared by multiple people) or inadequately secured to beds and didn't hang well around the bed.

So far, we have been using the DuraNet … when some of the little babies roll around and rub their skin on the net, the strong material scratches them because it is made of string. (youth, male, Jiwaka Province)

These string nets … sometimes when we want to sleep, we try to hang them up, but they don't hang properly and stay loose, so when we sleep, we're not well-protected, and mosquitoes can get inside. Those string nets aren't as good. (youth, female, Madang Province)

While community members referred to the different ITNs by their colour, few showed a preference for specific colours. However, one community member indicated a preference for the green colour of the SafeNet, while another indicated dark colours could cause the nets to feel hotter inside by 'blocking the wind', and therefore preferred lighter colours on nets.

I use a SafeNet like this net because I like sleeping under it. All these nets we get sometimes make us sweat, and then we feel hot because of their colors. When you put up the net, those dark colors block the wind, so I use a SafeNet … I like it because its color is light and it lets the wind come inside without blocking. (youth, male, New Ireland Province)

Size and shape

Community members frequently reported that ITNs were too small and cramped, particularly when multiple people had to share, demotivating individuals from sleeping under a net. Larger nets, sometimes referred to as 'double' nets, were preferred, which enabled people to sleep in the middle away from the sides of the net, avoiding skin irritation and the risk of mosquito biting.

For me, I feel that the mosquito net is still a bit small, so when I come back from roaming around, I feel lazy and just sleep outside. Because some of us feel that the net is still not big enough for us even if it is doubled, we still feel cramped. (adult, male, Madang Province)

Community members liked flexible nets which were able to stretch to accommodate people of different sizes or multiple people. Yorkool G1 ® and Yahe ® nets were perceived to be particularly flexible, spacious and comfortable to sleep inside.

In my opinion, the net I like is the Yorkool. The material they used is good; it's soft, and if you stretch it, it can cover a wide area. Even if you are a big person, you can roll around comfortably. (youth, male, Madang Province)

Discussion

This study highlights how a range of behavioural, socio-cultural and implementation-related factors can compromise ITN effectiveness in PNG and may thus contribute to the surge in malaria cases observed over the last decade.

For most people in this study, the main source of ITNs were the mass campaigns (71%), and continuous distribution channels (10%) that supply ITNs for free. These distribution channels are critical and had led to high coverage in the study villages. Yet, evidence also suggests that while giving away free ITNs may increase the number of people owning an ITN, it may not always translate to an increase in bed net use (19). In the present study, people self-reported high ITN use rates of 83%. However, this was not directly observed and may be subject to response bias leading to an overestimation of the true usage rates. Previous studies have reported this bias to range from – 6% to 23% (20).

The findings suggest that it may be worth considering widening the eligibility criteria to receive ITNs through continuous distribution mechanisms, which is currently primarily focused on pregnant women. It should also be considered that in PNG, 20% of pregnant women never visit a health facility and would thus not get an antenatal ITN (21). In Madagascar, a trial of community-based continuous distribution of ITNs to a wider range of community members (pregnant women, vaccinated children, people without a sleeping space covered, newly married couples, new arrivals to the village, and those with damaged nets) successfully provided ITNs to households requesting them and exceeded population ITN access targets (22). This suggests that broadening the criteria for continuous ITN distribution eligibility in PNG could help to ensure that people who are without an ITN between distribution rounds are able to access them more easily (23).

Some people acquire mosquito nets from shops (8%), suggesting that community members may look for ways to make up for gaps in coverage left by government distribution mechanisms. A recurrent theme was the reluctance to pay for ITNs as well as concerns around quality of store-bought ITNs. Currently the authors are unaware of any availability of prequalified ITN products in the private retail sector in PNG, even though there may be a demand. This gives end-users almost no other opportunity to

obtain a prequalified ITN, other than to wait for the next mass distribution. The private market in other countries has also been found to be dominated by untreated products (24). Public-private sector partnerships enabling availability of quality ITNs through the private retail sector has potential to address some of the coverage gaps and reduce the market share for ineffective untreated products (25). Overall, diversifying routes of how end-users can access prequalified ITN products could be effective in addressing coverage gaps and increasing usage (26).

Universal coverage is defined as the proportion households that own 1 ITN for every 2 people (27, 28). The household survey results indicated that 61% of survey households fulfilled this requirement, 3 years after the last mass distribution. This is promising and a high proportion by international comparison (29). Yet, households with more members were statistically significantly less likely to be 'universally covered', and many community members expressed dissatisfaction around the number of ITNs available to them in their households. Gender inequalities observed in ITN usage behaviours are likely rooted in socio-cultural factors such as mothers sharing ITNs with their children and men potentially foregoing ITN use for the benefit of other family members. However decision-making around who gets to use an ITN may be exacerbated by not enough ITNs being available.

Overall, some household-level indicators may potentially occlude gaps in access and use, and thus overestimate the success of ITN distribution programs (29). The present study suggests that this may, in part, also be the case in PNG.

Reasons for not using ITNs in PNG have previously been explored and this study identified many themes similar to those reported previously. By far the most frequent reason given for not using an ITN is that they are 'too hot' (6). Most of this is related to a feeling of reduced air flow in the humid, tropical climate of PNG, with a smaller proportion related to the burning skin sensation that many people experience when exposed to the insecticides, which was also directly identified by some people. About 8% of people said that using ITNs was too much work and they were not useful, and 6% complained about bed bugs. While concerns around physical damage and insecticidal efficacy also featured in the FGDs, they were raised by only a few participants.

Many community members also continue to use ITNs from previous rounds of distribution and only gradually replace them with fresh campaign nets. In the present study, 30% of ITNs predated the last distribution campaign, and 21% of inspected ITNs that had not been used to previous night were indicated to be kept for later use. These findings are corroborated by the results of a recent review of national household survey data highlighting how the most common reason for ITN non-use is saving them for future use [17]. The review showed that this behaviour was particularly frequent among households owning more ITNs than deemed strictly necessary by the WHO (17), potentially reflecting the inefficiencies of ITN distribution systems wherein some households have too few ITNs while others have too many (30). This may indicate that effectively supplying ITNs to those in need becomes more difficult as coverage increases (31).

The findings also highlight that communities would benefit from more support during and after ITN distribution campaigns. Community engagement is critical for ensuring trusting relationships are established with communities and can ultimately help to increase ITN acceptability (32). While community volunteers are well placed to interact with communities during distribution, adequate resourcing is required to ensure they are adequately paid and properly trained to incentivise good performance and support effective educational interventions. Comprehensive information, education and awareness resources, tailored for the types of local knowledge and needs in different communities, would support net distribution teams to communicate key messages around ITN set up, handling and maintenance to communities. In particular, nuance is required to transparently communicate inevitable trade-offs (e.g., comfort vs. durability) when using different types of ITN, to enable community members to make informed choices around net preference and usage. Distribution teams must actively engage with community concerns around bed bug infestation and side effects from ITNs, which are key factors driving low net usage in some communities.

Polyester products (for example SafeNet ®, Yahe ®, Yorkool G1 ® and Interceptor G2 ®) were associated with being soft, flexible, breathable and easy to arrange, and were strongly preferred by most participants. These ITNs were also associated with reduced the intensity of unpleasant side effects by community members, such as overheating when using nets, skin irritation, and rolling/folding up when disturbed. This is similar to previous studies in African, South Asian and Pacific Islands settings (33–35). Distribution of these ITN types may thus increase effectiveness through increased community acceptability and compliance with use. Unfortunately, there are concerns around the duration of insecticidal efficacy for a range of pyrethroid-only polyester products in PNG and elsewhere (36–40), which would likely outweigh these benefits.

Although community members liked the durability of nets such as MAGNet and DuraNet, they were generally unpopular choices and demotivated use. While recent evidence indicates that ITN attributes such as size, shape, colour and texture are minor reasons for not using nets (17), our findings suggest that community members see these attributes as linked to experiences of excessive heat and skin irritation. Further research investigating product-specific differences in insecticidal efficacy and more detailed qualitative research on reasons for net non-use will help to ensure that the most appropriate nets are procured to control malaria in PNG.

A major limitation of this study was that the qualitative and quantitative components were not conducted in the same villages (apart from one village in Madang Province), limiting the direct comparability of these findings by site and our ability to draw out detailed site-specific differences. Another was the use of convenience sampling, which may have failed to capture important perspectives from people who are either difficult to reach or difficult to engage in the study.

Despite these limitations, our study demonstrates how a mixed-methods approach can offer a holistic understanding of the complexities of ITN access and use, highlighting and contextualising the

coherences and discrepancies between quantifiable aspects of ‘how’ people are receiving and using (or not using) ITNs and the qualitative explanations of ‘why’ this is the case.

Based on these findings, the following recommendations to improve ITN access and use in PNG are proposed (Box 1).

Box 1: Recommendations to improve ITN access and usage in PNG

- After confirming insecticidal efficacy, select ITN products which best align with community preferences for soft, breathable, low irritant polyester products
- Review distribution key to ensure universal coverage of ITNs, accounting for household structure, sleeping preferences and local cultural norms
- Strengthen community engagement during ITN distributions and develop contextually relevant educational approaches and resources on ITNs
- Diversify continuous distribution mechanisms, especially through public-private partnerships, to increase access and use

Conclusions

This study provides a nuanced understanding of the factors shaping ITN access and use in PNG. While household ownership and reported usage remain relatively high three years after mass distribution, important gaps persist beneath these indicators. Coverage shortfalls in larger households, gendered decision-making around net sharing, seasonal and situational non-use, concerns about side effects and bed bugs, and dissatisfaction with certain ITN features all interact to reduce the effectiveness of protection from ITNs. The findings suggest that implementation-related challenges, including limitations of the current distribution key, restricted access through continuous distribution channels, insufficient community engagement, and limited post-distribution support, also undermine optimal net allocation and consistent use. At the same time, community preferences for softer, breathable polyester nets highlight the importance of aligning procurement decisions with user views on acceptability, while carefully balancing concerns about insecticidal durability and efficacy. Addressing the resurgence of malaria in PNG will require a more person-centred and contextually grounded approach to ITN programming - refining distribution strategies to better reflect household composition, diversifying access pathways, strengthening community engagement and education, and transparently communicating trade-offs may collectively enhance access and usage, and support progress toward sustained malaria control in PNG.

Abbreviations

ITN – Insecticide Treated Net

PNG – Papua New Guinea

WHO – World Health Organization

Declarations

Ethics approval and consent to participate

Ethical approval was received prior to the beginning of the research. The qualitative component was approved under the Global Fund Net Transition Initiative by the PNG Institutional Review Board (IRB, #2402) and PNG Medical Research Advisory Committee (MRAC, 23.03). The quantitative component was approved under Stronger Surveillance and Systems Support for Rapid Identification and Containment of Resurgent or Resistant Vector Borne Pathogens in Papua New Guinea (STRIVE PNG) project by the PNG Institutional Review Board (IRB, #1901) and PNG Medical Research Advisory Committee (MRAC, 19.12). Written informed consent was obtained from all participants prior to their participation in the study.

Consent for publication

Not applicable

Availability of data and materials

The research data are confidential and are not publicly available. Excerpts of selected transcripts have been made available within the paper. Access to the de-identified minimal dataset can be provided on reasonable request. Please contact the PNGIMR Institutional Review Board on: imrirb@pngimr.pg.org

Competing interests

The authors declare no competing interests.

Funding

The study was funded by the Global Fund to Fight Aids Tuberculosis and Malaria (TO 2023-005892). LJR was supported by Australian National Health and Medical Research Council Leadership-1 Investigator Award and the work was in part supported by the award's Research Support Package (GNT2017630). The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author contributions

Raised Funding: SK, LJR*; Field work:* JBK, JC, CA, CP, MM, CF; *Study design/Coordination:* BE, JBK, MO, LJR, ML, SK, *Analysis:* BE, JBK, MK, SK; *First Draft:* BE, JBK, MK SK; *Manuscript Review:* all authors

Acknowledgments

The authors would like to acknowledge the participating households and volunteers, and the support received from the PNG National Malaria Control Program, Provincial Health Authorities and Rotarians Against Malaria PNG. We thank the PNGIMR Entomology staff and the logistical and administrative support provided by PNGIMR. Tim Freeman for advice.

References

1. WHO. World malaria report 2024. World Health Organization2024.
2. Papua New Guinea National Department of Health, National Malaria Strategic Plan, 2021-26: Strengthening malaria control, moving towards elimination (updated Oct. 2023). 2023.
3. Hetzel MW, Saweri OP, Kuadima JJ, Smith I, Ura Y, Tandrapah A, et al. Papua New Guinea malaria indicator survey 2016–2017: Malaria prevention, infection, and treatment. Goroka: Papua New Guinea Institute of Medical Research. 2018:202016–17.
4. Vinit R, Timinao L, Bubun N, Katusele M, Robinson LJ, Kaman P, et al. Decreased bioefficacy of long-lasting insecticidal nets and the resurgence of malaria in Papua New Guinea. Nature communications. 2020;11(1):3646.
5. Bubun N, Anetul E, Koinari M, Freeman TW, Karl S. Coating formulation change leads to inferior performance of long-lasting insecticidal nets in Papua New Guinea. Malaria Journal. 2022;21(1):349.
6. Rodriguez-Rodriguez D, Katusele M, Auwun A, Marem M, Robinson LJ, Laman M, et al. Human Behavior, Livelihood, and Malaria Transmission in Two Sites of Papua New Guinea. J Infect Dis. 2021;223(12 Suppl 2):S171–S86.
7. Cleary E, Hetzel MW, Clements ACA. A review of malaria epidemiology and control in Papua New Guinea 1900 to 2021: Progress made and future directions. Frontiers in Epidemiology. 2022;2.
8. Millat-Martínez P, Gabong R, Balanza N, Luana S, Sanz S, Raulo S, et al. Coverage, determinants of use and repurposing of long-lasting insecticidal nets two years after a mass distribution in Lihir Islands, Papua New Guinea: a cross-sectional study. Malaria Journal. 2021;20(1):336.
9. Giduthuri JG, Timbi D, Kualawi M, Are C, Muri M, Goi P, et al. Papua New Guinea Malaria Indicator Survey 2022-2023: Final report of malaria prevention, infection prevalence, and treatment-seeking. PNGIMR, Swiss TPH2024.

10. Bannister-Tyrrell M, Verdonck K, Hausmann-Muela S, Gryseels C, Muela Ribera J, Peeters Grietens K. Defining micro-epidemiology for malaria elimination: systematic review and meta-analysis. Malar J. 2017;16(1):164.
11. Radford A, Van Leeuwen H, Christian S. Social aspects in the changing epidemiology of malaria in the highlands of New Guinea. Annals of Tropical Medicine & Parasitology. 1976;70(1):11–23.
12. Gul D, Rodriguez-Rodriguez D, Nate E, Auwan A, Salib M, Lorry L, et al. Investigating differences in village-level heterogeneity of malaria infection and household risk factors in Papua New Guinea. Sci Rep. 2021;11(1):16540.
13. Keven JB, Reimer L, Katusele M, Koimbu G, Vinit R, Vincent N, et al. Plasticity of host selection by malaria vectors of Papua New Guinea. Parasit Vectors. 2017;10(1):95.
14. Hofmann NE, Karl S, Wampfler R, Kiniboro B, Teliki A, Iga J, et al. The complex relationship of exposure to new Plasmodium infections and incidence of clinical malaria in Papua New Guinea. Elife. 2017;6.
15. Pulford J, Oakiva T, Angwin A, Bryant M, Mueller I, Hetzel MW. Indifferent to disease: A qualitative investigation of the reasons why some Papua New Guineans who own mosquito nets choose not to use them. Social Science & Medicine. 2012;75(12):2283–90.
16. Ladu HI, Shuaibu U, Pulford J. Reasons for mosquito net non-use in malaria-endemic countries: A review of qualitative research published between 2011 and 2021. Tropical Medicine & International Health. 2024;29(7):647–56.
17. Koenker H, Kumoji EK, Erskine M, Opoku R, Sternberg E, Taylor C. Reported reasons for non-use of insecticide-treated nets in large national household surveys, 2009–2021. Malaria Journal. 2023;22(1):61.
18. Hetzel MW, Gideon G, Lote N, Makita L, Siba PM, Mueller I. Ownership and usage of mosquito nets after four years of large-scale free distribution in Papua New Guinea. Malaria Journal. 2012;11(1):192.
19. Polec LA, Petkovic J, Welch V, Ueffing E, Ghogomu ET, Pardo JP, et al. Strategies to Increase the Ownership and Use of Insecticide-Treated Bednets to Prevent Malaria. Campbell Systematic Reviews. 2015;11(1):1–127.
20. Krezanoski PJ, Bangsberg DR, Tsai AC. Quantifying bias in measuring insecticide-treated bednet use: meta-analysis of self-reported vs objectively measured adherence. J Glob Health. 2018;8(1):010411.
21. National Statistical Office NSO, Icf. Papua New Guinea Demographic and Health Survey 2016-18. Port Moresby, Papua New Guinea: NSO and ICF; 2019.
22. de Beyl CZ, Kilian A, Brown A, Sy-Ar M, Selby RA, Randriamanantenasoa F, et al. Evaluation of community-based continuous distribution of long-lasting insecticide-treated nets in Toamasina II District, Madagascar. Malaria Journal. 2017;16(1):327.
23. Kilian A, Woods Schnurr L, Matova T, Selby RA, Lokko K, Blaufuss S, et al. Evaluation of a continuous community-based ITN distribution pilot in Lainya County, South Sudan 2012-2013. Malar J.

2017;16(1):363.
24. Kamala B, Loll D, Msolla R, Dadi D, Gitanya P, Mwalimu C, et al. Persistence of Untreated Bed Nets in the Retail Market in Tanzania: A Cross-Sectional Survey. Tropical Medicine and Infectious Disease. 2025;10(6):175.
25. Olapeju B, Choiriyyah I, Bertram K, Piccinini D, Harig H, Selby RA, et al. Who buys nets? Factors associated with ownership and use of purchased mosquito nets in sub-Saharan Africa. Malar J. 2019;18(1):401.
26. Krezanoski PJ. Delivering insecticide-treated nets for malaria prevention: innovative strategies. Res Rep Trop Med. 2016;7:39–47.
27. Zhou G, Li JS, Ototo EN, Atieli HE, Githeko AK, Yan G. Evaluation of universal coverage of insecticide-treated nets in western Kenya: field surveys. Malar J. 2014;13:351.
28. WHO. Achieving universal coverage with long-lasting insecticidal nets in malaria control: recommendation. 2013.
29. Koenker H, Arnold F, Ba F, Cisse M, Diouf L, Eckert E, et al. Assessing whether universal coverage with insecticide-treated nets has been achieved: is the right indicator being used? Malaria Journal. 2018;17(1):355.
30. Bhatt S, Weiss DJ, Mappin B, Dalrymple U, Cameron E, Bisanzio D, et al. Coverage and system efficiencies of insecticide-treated nets in Africa from 2000 to 2017. Elife. 2015;4:e09672.
31. Bertozzi-Villa A, Bever CA, Koenker H, Weiss DJ, Vargas-Ruiz C, Nandi AK, et al. Maps and metrics of insecticide-treated net access, use, and nets-per-capita in Africa from 2000-2020. Nature Communications. 2021;12(1):3589.
32. Awasthi KR, Jancey J, Clements ACA, Rai R, Leavy JE. Community engagement approaches for malaria prevention, control and elimination: a scoping review. BMJ Open. 2024;14(2):e081982.
33. Atkinson J-A, Bobogare A, Vallely A, Boaz L, Kelly G, Basifiri W, et al. A cluster randomized controlled cross-over bed net acceptability and preference trial in Solomon Islands: community participation in shaping policy for malaria elimination. Malaria Journal. 2009;8(1):298.
34. Das ML, Singh SP, Vanlerberghe V, Rijal S, Rai M, Karki P, 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.
35. Hien H, Hien AS, Bacyè FY, Badolo H, Tiono A, Diallo CO, et al. Assessing ITN textile preferences: A comparative study of polyethylene and polyester nets across different settings in Burkina Faso. PLoS One. 2025;20(8):e0325580.
36. Vinit R, Timinao L, Bubun N, Katusele M, Robinson LJ, Kaman P, et al. Decreased bioefficacy of long-lasting insecticidal nets and the resurgence of malaria in Papua New Guinea. Nat Commun. 2020;11(1):3646.
37. Bubun N, Anetul E, Koinari M, Freeman TW, Karl S. Coating formulation change leads to inferior performance of long-lasting insecticidal nets in Papua New Guinea. Malar J. 2022;21(1):349.

38. Bubun N, Anetul E, Koinari M, Johnson PH, Makita LS, Freeman TW, et al. Insufficient duration of insecticidal efficacy of Yahe((R)) insecticide-treated nets in Papua New Guinea. Malar J. 2024;23(1):175.
39. Mbwambo SG, Bubun N, Mbuba E, Moore J, Mbina K, Kamande D, et al. Comparison of cone bioassay estimates at two laboratories with different Anopheles mosquitoes for quality assurance of pyrethroid insecticide-treated nets. Malar J. 2022;21(1):214.
40. Villalta EL, Soto Bravo AM, Vizcaino L, Dzuris N, Delgado M, Green M, et al. Evaluation of the durability and use of long-lasting insecticidal nets in Nicaragua. Malaria Journal. 2021;20(1):106.

Figures

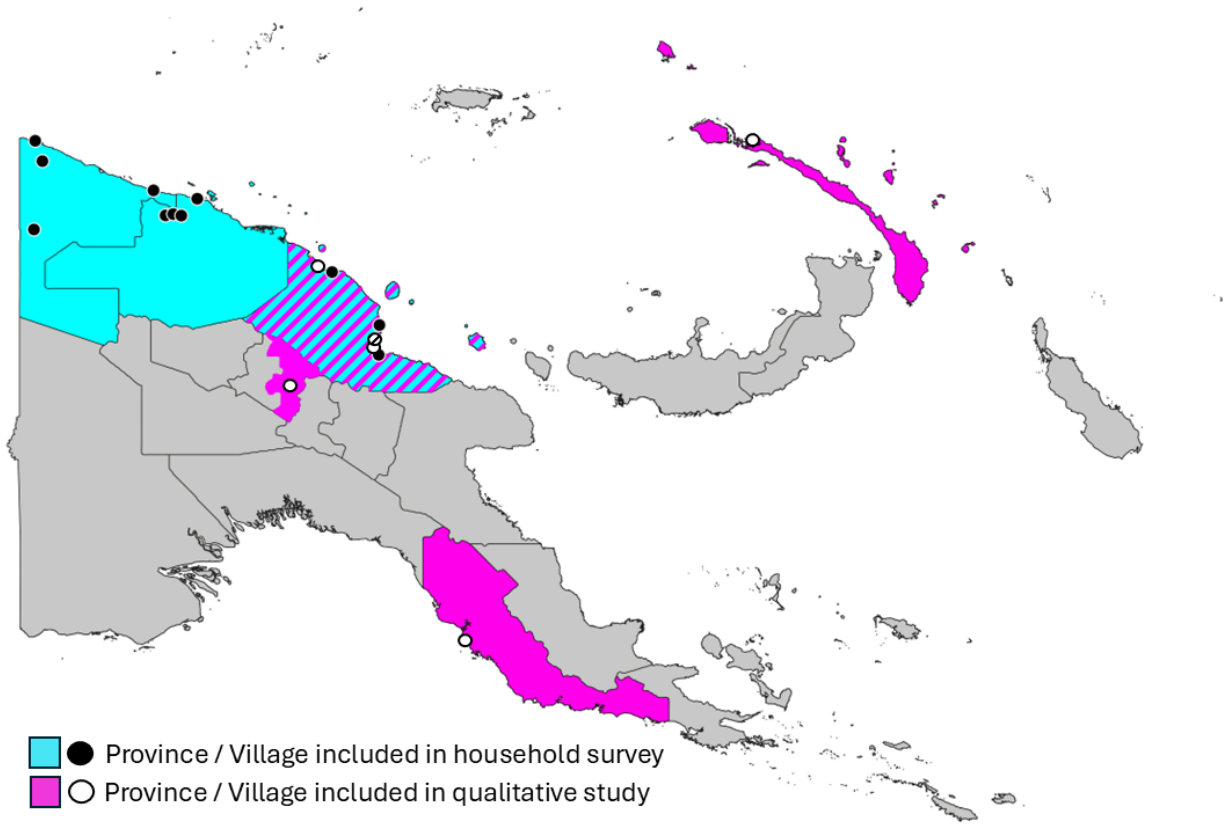


Figure 1

Map showing the study provinces and villages. Provinces and villages part of the qualitative and quantitative studies are separately identified. Provinces and villages where both qualitative and quantitative data were collected are indicated with a hash pattern containing both colours.

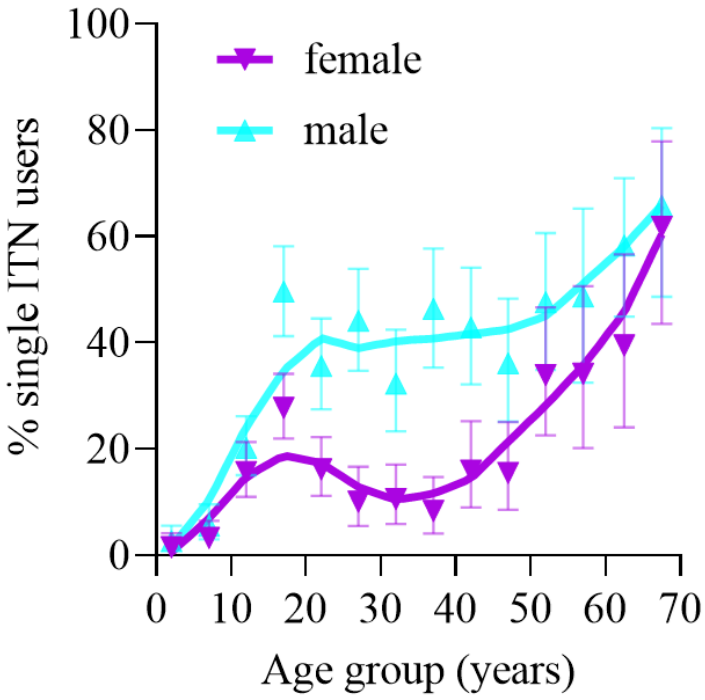


Figure 2

Gender-based use of ITNs. The plot shows the percentage of ITNs used by a single person. The symbols indicating data are the averages per age group. The error bars are the 95% confidence levels of the percentages. The curves are the result of locally estimated scatterplot smoothing (LOESS), intended as guides to the eye.

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- S1File.docx
- S2File.docx