

Mosquito Net Ownership, Utilization, and Preferences among Mobile and Migrant Populations Sleeping in Forests and Farms in Central Vietnam: A Cross-Sectional Study

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Abstract. Strengthening vector control measures among mobile and migrant populations (MMPs) is crucial to malaria elimination, particularly in areas with multidrug-resistant malaria. Although a global priority, providing access and ensuring high coverage of available tools such as long-lasting insecticidal nets (LLINs) among these vulnerable groups remains a significant challenge. We assessed mosquito net ownership, utilization, and preference among individuals who slept in a forest and/or on a farm against those residing only in village “home” settings in a priority malaria elimination area of Vietnam. Proportions of respondents owning bed nets were similar among forest, farm, and home sleeping sites, ranging between 96% and 98%. The proportion of respondents owning hammock nets was higher for the forest group (92%), whereas ownership of hammocks in general was significantly lower for the home group (55%). Most respondents (97%) preferred to bring hammock nets to their remote sleeping site, whereas a smaller proportion (25%) also considered bed nets as an option. Respondent preferences included thick hammock nets with zippers (53%), hammocks with a flip cover (17%), and thin hammock nets with zippers (15%), with none choosing polyethylene (hard) LLINs. Although there is high coverage and access to nets for this high-priority MMP group, there was a noted gap between coverage and net use, potentially undermining the effectiveness of net-related interventions that could impact malaria prevention and elimination efforts in Vietnam. The design and material of nets are important factors for user preferences that appear to drive net use.

INTRODUCTION

Enhancing vector control strategies, including optimizing long-lasting insecticidal net (LLIN) coverage among populations vulnerable to malaria transmission, remains at the core of contemporary global malaria elimination policy.^{1,2} To achieve the desired outcomes, the WHO recommends National Malaria Control Programs (NMCPs) conduct routine mass LLIN distribution campaigns and establish continuous distribution channels in areas at risk of malaria to achieve high coverage and universal access.³ To ensure optimal service delivery and maximize the impact of vector control strategies, NMCPs must have effective surveillance, implementation, and monitoring and evaluation systems in place to ensure LLIN distribution is targeted and nets are used appropriately.

The use of insecticide-treated bed nets (ITNs) and LLINs currently remains a frontline intervention for global elimination. However, evidence from studies within the Greater Mekong Subregion (GMS) has shown that although these measures are generally effective in improving malaria outcomes, their impacts are not as robust as those seen in sub-Saharan Africa.^{4–8} There is a need to explore new and innovative vector control tools and approaches to address the issues of outdoor transmission and forest malaria that specifically target the high-risk populations frequenting these areas.^{1,2,4–11} Although the complex vector biology within the GMS, particularly the early and outdoor biting preferences of priority malaria vectors inhabiting forested habitats such as *Anopheles dirus*, is likely to limit the overall impact of ITNs as a stand-alone intervention in these environments, available evidence still supports the use of these tools as part of an integrated approach to malaria elimination in the region.^{4,12} Given the

current limited availability of proven malaria transmission reduction tools such as ITNs, it is imperative that malaria programs ensure these interventions are distributed at optimal levels to cover at-risk populations for maximum effect.¹²

In the GMS, epidemiological challenges associated with the biology of outdoor biting mosquito vectors, high numbers of mobile and migrant populations (MMPs)—including individuals frequently working and sleeping in forests—and drug-resistant malaria highlight the difficulties and importance of eliminating malaria in the region.^{6,11,13–18} These challenges are reflected in findings from Vietnam, where more than 60% of local malaria transmission has been found among individuals sleeping and working in forests and forest-fringe farms.⁸ In Vietnam, the primary malaria vector, *A. dirus*, is an exophagic mosquito that inhabits forest and forest-fringe environments with recorded early evening biting behavior.^{16,17} Previous studies have shown that the use of long-lasting insecticide-treated hammock nets (LLHNs) has resulted in a significant reduction of *A. dirus* in the GMS.^{5,7,19} Although the number of studies on the protective impacts of LLHN use in the GMS is limited, data that are available indicate that LLHNs are likely to be effective as a supplementary tool to protect individuals sleeping in forest and forest-fringe farm settings.

Mosquito nets, including conventional ITNs, LLINs, and LLHNs, are a key component of vector control in Vietnam. The Regional Artemisinin-resistance Initiative (RAI), funded by the Global Fund to Fight AIDS, Tuberculosis, and Malaria, is a major supporter of malaria elimination programs in the GMS through a variety of activities, including the procurement and distribution of insecticide-treated nets, including in Vietnam.^{20,21} Until 2009, many more ITNs than LLINs were in use in the country.^{16,22} However, the Global Fund supported expansion of LLIN availability, increasingly replacing ITNs with supplemental single LLINs or LLHNs, to all users including mobile populations and forest-goers.

A specific objective of Vietnam’s current National Strategy for Malaria Control and Elimination is to ensure the coverage of

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appropriate control measures for all people at risk of malaria. In addition to ensuring optimal coverage of LLINs among high-risk populations, it is essential to ensure the use of these tools within their intended settings. Limited studies of net usage among MMPs in the GMS have indicated that barriers exist among these diverse populations, including insufficient access to nets, difficulties in transporting and carrying ITNs, and a perceived dislike of nets.^{23,24} In addition to expanding access, improving compliance and usage of bed nets should consider sociocultural contexts of target populations, as well as take into account key considerations such as acceptability and preference of net characteristics and type.²⁵ Given the significant number of MMPs working in forest and farm settings within Vietnam, there is a need to explore and evaluate current net usage among these hard-to-reach populations. To provide a current assessment of mosquito net use and preference among high-risk individuals, a cross-sectional survey was conducted in three forested and mountainous communes in Central Vietnam.

MATERIALS AND METHODS

Study site. The study was conducted in three forested and mountainous communes, comprising multiple villages, within Dong Xuan district, Phu Yen Province in South-Central Vietnam: Phu Mo, Xuan Lanh, and Xuan Quang 1 communes. These communes were selected because of their epidemiological significance and geographic location, including a relatively high number of reported malaria infections, a large number of forest-fringe communities and individuals frequenting and sleeping in the forest for their livelihood, and geographic location directly adjacent to two “Tier 1 Artemisinin Resistant” provinces as defined by the WHO global plan for artemisinin resistance containment.²⁶ The study site is also included as part of the current RAI supported program implementation in Vietnam, focusing on strengthening malaria service coverage of remote and at-risk populations.²¹

Study design. This cross-sectional survey conducted between August and September 2016 was part of a larger, detailed malaria survey within the study area.^{27,28} Of the 4,668 households that were recorded and mapped in 18 villages within the three study-site communes, 1,083 households were randomly selected for inclusion in the survey. A semi-structured interviewer-administered questionnaire was developed based on a literature review of malariometric surveys and with input from the research team. The survey was administered through face-to-face household-based interviews with the identified head of household. A key component of the survey design was to distinguish between the head of household respondents who self-reported they travel, work, and sleep in forest and/or farm locations versus those who did not. Questions were developed to collect information on participant location, demographics, mosquito net ownership, use, preference, and malaria exposure behavioral risk. The questionnaire was initially developed in English and subsequently translated into Vietnamese by local malaria staff. Household interviews were primarily conducted in Vietnamese, as well as local ethnic minority language when required. The questionnaire was pretested among a small sample of respondents from the target population. Most of the questions had predefined categories, with some open-ended questions also included. When the head of the household was

unavailable, interviews were conducted with the associated household member as a replacement household head respondent. Only survey respondents between the ages of 18 and 70 years were included.

Descriptions of mosquito nets as they appear in the market were used in the questionnaire. Following options for untreated nets or hammocks were included: untreated single net, untreated double net, hammock without net, untreated hammock-net, thin net with a zipper, untreated hammock-net, thick net with a zipper, and hammock with a net flip over. Hammock nets with a zipper refer to hammocks where the net and hammock is a single unit, with a zipper opening. Hammocks with a flip over refer to hammocks with a separate net unit that fits over the hammock. Treated net and hammock options included the following: treated single net, treated double net, single polyester LLIN, double polyester LLIN, single polyethylene LLIN, double polyethylene LLIN, and LLIN hammock net. Nets described herein as “soft” refer to polyester nets and “hard” refer to polyethylene nets. Mosquito nets within the household were also observed, physically inspected, and photographed where possible. Interview teams also provided examples of net types to interviewees to aid in the categorization of nets, where required.

Data collection and analysis. Survey data were collected using a smartphone-based data collection software (KLL Collect, Kathmandu Living Labs, Kathmandu, Nepal) and uploaded to web-based data storage and visualization platform (Ona Systems, Nairobi, Kenya). The National Institute of Malariology, Parasitology, and Entomology (NIMPE), and project staff provided training to district- and commune-level health personnel on survey, interview, and data collection procedures. Interviews and data collection were conducted by NIMPE, and district- and commune-level health staff. Data were analyzed using XLSTAT-Base statistical application for Microsoft Excel version 2018.7 (Addinsoft, Paris, France). Categorical variables were compared using Chi square analysis. In the case of statistically significant test result of multiple proportion comparison, the Marascuilo procedure was used to identify the proportion(s) responsible for the rejection of the null hypothesis. Logistic regression models were used to calculate prevalence odds ratios (PORs) and 95% CIs to assess differences of characteristics among those who slept in forests and/or farms. A significance level of $P < 0.05$ was set for all statistical tests.

Ethical considerations. The study protocol was reviewed and approved by NIMPE’s Institutional Review Board in Hanoi, Vietnam (Protocol number: 2016-VM-P1; IRB number: IRB00010326; date: August 10, 2016) and the U.S. Naval Medical Research Unit Two (NAMRU-2) Human Research Protection Office (HRPO.NMRCA.2016.0002; date: August 11, 2016). Written informed consent was obtained from all study participants. All information collected from survey participants was kept confidential and de-identified to remove personal information. Raw data files were also de-identified and stored in secure, password-protected electronic files.

RESULTS

Of the 1,083 households selected, nine households did not meet the household head respondent inclusion criteria and were excluded from the study. A total of 4,211 individuals were captured in the survey, including 1,074 household head

respondents and 3,137 additional associated household members. Table 1 summarizes the types of nets owned by household respondents that self-reported having slept in remote forest and/or farm sites within the last year.

Of the 1,074 respondents, 472 (43.9%) reported to have slept in the forest, 92 (8.6%) slept on a farm, 132 (12.3%) slept at both forest and farm sites, and 378 (35.2%) had not slept at either a forest or on a farm (slept at home) within the last 12 months. In general, there were no significant differences in the types of nets owned by respondents by sleeping site location, with the exception of untreated nets. There were no respondents that reported owning untreated nets who slept on farms (ES; ES Cramer's $V = 0.05$; reciprocal differences between forest, both sites and home groups were not statistically significant). Treated nets were the most common type of net used by study respondents (ranging from 88.1% at home to 95.7% on farm).

The proportion of respondents not owning any hammock net was significantly higher for those reporting to only sleeping at home (45.2%) than for other groups (ranging from 8.3%–10.6%), with moderate association between sleeping site and number of respondents not owning any hammock nets ($\chi^2 (3; 1,074) = 192.8, P < 0.0001$, ES Cramer's $V = 0.24$; reciprocal differences among forest, farm, and both sites' groups were not statistically significant). The proportion of respondents owning hammocks without a net was significantly lower for the home group than for forest, farm, and both sites' groups; however, a small ES indicated a weak association between sleeping site and ownership of hammock without a net ($\chi^2 (3; 1,074) = 81.9, P < 0.0001$, ES Cramer's $V = 0.16$; reciprocal differences among forest, farm, and both sites' groups were not statistically significant). A statistically significantly higher proportion of respondents sleeping at forest sites owned hammock nets than those who slept at other sites ($\chi^2 (3; 1,074) = 54.7, P < 0.0001$), but the association between sleeping site and hammock net ownership was weak, as indicated by the small ES (ES Cramer's $V = 0.13$; only differences between forest and both sites' groups and forest and home groups were statistically significant). Hammocks without nets were the most common type of hammock owned by respondents (ranging from 44.7% at home to 71.2% at both sites).

Respondents reported using a total of 3,366 nets/hammocks. These included treated and untreated single and double bed nets; single and double, soft and hard LLIN bed

nets; hammock nets with zipper and flip over; and hammocks without a net (Table 2). Of all net and hammock types used, 816 were used in the forest, 375 were used on a farm, and 2,854 were used at home. Respondents reported using the same net/hammock at one or more sleeping sites or owning, but not using nets. Thus, numbers in the "Total" column of Table 2 do not always equate to the sum of nets used at different sleeping sites. Results indicate that on average, each participating household used about two nets and a hammock. Most of the nets/hammocks were used at home, followed by on farms and then in the forest where only one net/hammock was generally used.

Bed nets were preferred over hammocks among the overall study population (62.5% versus 37.5%). Across all sleeping sites, bed nets were used mostly at home (69.2%), whereas hammocks were predominantly used in the forest (88.2%) and on farms (78.7%). The difference between sleeping sites was statistically significant ($\chi^2 (2; 4,045) = 1,010.4, P < 0.001$), with a moderate association between sleeping sites and the number of owned bed nets (ES Cramer's $V = 0.35$; reciprocal differences between three sleeping sites were statistically significant).

At home, the most common type of bed net was treated bed nets (53.5% of bed nets used at home), followed by soft LLIN bed nets (27.3%), hard LLIN bed nets (11.0%), and untreated bed nets (8.1%). Treated bed nets and soft LLIN bed nets were most common types used in forests (35.4% and 32.3% of bed nets used in forest, respectively), whereas soft LLIN bed nets comprised 61.3% of bed nets used on farms.

Hammocks without a net were the most commonly used hammocks at all sleeping sites, accounting for 69.2% of those used in forests, 83.4% of those used on farms, and 83.8% of those used at home. Although the difference in proportions was statistically significant ($\chi^2 [2; 1893] = 55.4, P < 0.0001$), it had low practical significance, as the association between sleeping sites and the number of owned hammocks was weak (ES Cramer's $V = 0.12$; difference between farm and home sleeping sites was not statistically significant). The difference in proportions of hammock nets with a zipper between all three sleeping sites was not statistically significant (14.0% of all hammocks in forest, 9.8% on farms, and 10.8% at home; $\chi^2 (2; 1893) = 5.3, P = 0.071$, ES Cramer's $V = 0.04$). The proportion of hammocks with flip over was significantly higher for the forest group than for other sleeping sites (16.8% of all hammocks used

TABLE 1

Summary of the types of nets owned by household head respondents sleeping at least one night in a remote forest and/or farm site within the last year of the survey

Net ownership	Slept in forest (<i>n</i> = 472), <i>n</i> (%)	Slept at farm (<i>n</i> = 92), <i>n</i> (%)	Slept at both sites (<i>n</i> = 132), <i>n</i> (%)	Slept only at home (<i>n</i> = 378), <i>n</i> (%)	Total (<i>n</i> = 1,074), <i>n</i> (%)	<i>P</i> -value; Cramer's <i>V</i>
Bed nets						
Does not own bed net	10 (2.1)	3 (3.3)	5 (3.8)	9 (2.4)	27 (2.5)	0.703; 0.04
Untreated net	36 (7.6)	0 (0.0)	5 (3.8)	28 (7.4)	69 (6.4)	0.035*; 0.05*
Treated net	411 (87.1)	88 (95.7)	115 (87.1)	332 (87.8)	946 (88.1)	0.199*; 0.04*
Untreated and treated nets	15 (3.2)	1 (1.1)	7 (5.3)	9 (2.4)	32 (3.0)	0.247; 0.04
Hammock nets						
Does not own hammock net	39 (8.3)	8 (8.7)	14 (10.6)	171 (45.2)	232 (21.6)	< 0.0001; 0.24
Hammock without a net	288 (61.0)	65 (70.7)	94 (71.2)	169 (44.7)	616 (57.0)	< 0.0001†; 0.16†
Hammock with a net	92 (19.5)	11 (12.0)	10 (7.6)	24 (6.3)	137 (12.8)	< 0.0001†; 0.13†
Hammocks with and without nets	53 (11.2)	8 (8.7)	14 (10.6)	14 (3.7)	89 (8.3)	0.001; 0.07

* Respective counts also include respondents that nominated using a combination of treated and untreated bed nets.

† Respective counts also include respondents that nominated using a combination of treated and untreated hammock nets.

TABLE 2
Number and type of nets and hammocks used at home, in forests, and on farms by study respondents

Nets/hammocks used	Forest	Farm	Home	Total
All types of nets	96	80	1976	2,105
% of all types of nets in total ($n = 2,105$)	4.6	3.8	93.9	100.0
Number of nets per household	0.2	0.4	5.2	1.7
All types of hammock	720	295	878	1,261
% All types of hammocks in total ($n = 1,261$)	57.1%	23.4%	69.6%	100.0%
Number of hammocks per household	1.2	1.3	2.3	1.0
Total nets and hammock used	816	375	2,854	3,366
Number of nets and hammocks per household	1.4	1.7	7.6	2.8
Untreated bed net (n)	18	3	161	169
% of all types of nets by sleeping location	18.8	3.8	8.1	8.0
Untreated single bed net	6	0	17	21
Untreated double bed net	12	3	144	148
Treated bed net (n)	34	14	1,058	1,078
% All types of nets by sleeping location	35.4%	17.5%	53.5%	51.2%
Treated single bed net	7	2	129	136
Treated double bed net	27	12	929	942
Polyester (soft) LLIN bed net (n)	31	49	540	606
% All types of nets by sleeping location	32.3%	61.3%	27.3%	28.8%
Soft LLIN single bed net	2	3	20	24
Soft LLIN double bed net	29	46	520	582
Polyethylene (hard) LLIN bed net (n)	13	14	217	252
% All types of nets by sleeping location	13.5%	17.5%	11.0%	12.0%
Hard LLIN single bed net	4	1	72	78
Hard LLIN double bed net	9	13	145	174
Hammock without a net (n)	498	246	736	985
% All types of hammocks by sleeping location	69.2%	83.4%	83.8%	78.1%
Hammock net with zipper (n)	101	29	95	158
% All types of hammocks by sleeping location	14.0%	9.8%	10.8%	12.5%
Thin hammock net with zipper	10	3	15	23
Thick hammock net with zipper	91	26	80	135
Hammock with flip over (n)	121	20	47	118
% All types of hammocks by sleeping location	16.8%	6.8%	5.4%	9.4%
RAI hammock net	27	10	21	33
Hammock with flip over	94	10	26	85

LLIN = long-lasting insecticidal net; RAI = Regional Artemisinin-resistance Initiative.

in forest, 6.8% on farms, and 5.4% at home; χ^2 (2; 1893) = 61.9, $P < 0.0001$). However, this was low practical significance, as measured by small ES (ES Cramer's $V = 0.13$; difference between farm and home sleeping sites was not statistically significant), and therefore represents a weak association between sleeping sites and the number of owned hammocks with flip over (Table 2).

Among the respondents who self-reported to have slept in either the forest or on a farm, 301 (43.2%) participants elected to answer an extended component of the survey relating to net/hammock usage and preference while sleeping in their respective remote sites away from their village-based home. Respondents included 258 individuals who slept in forests and 43 on farms. Table 3 provides a summary of the self-reported net use of respondents while sleeping at their remote area sites.

Of these forest and farm-going respondents, 291 (96.7%) indicated they would like to bring hammock nets to their sleeping sites; of those, 155 (53.3%) preferred thick hammock nets with a zipper enclosure, 49 (16.8%) preferred hammocks

with a flip cover enclosure, and 44 (15.1%) preferred thin hammock nets with a zipper enclosure (Table 4). Thick hammock nets with zippers were the preferred type among forest (138; 55.2%) and farm workers (17; 41.5%), with no significant difference between the two groups (POR = 1.74; 95% CI 0.90, 3.37). Farm workers also favored thin hammocks with a zipper enclosure (18; 43.9%) and were more likely to bring these hammock nets to their sleeping site (POR = 0.15; 95% CI 0.07, 0.31) than forest-goers.

Of respondents who slept in forests, 49 (19.6%) wanted to bring hammocks with a flip cover, whereas no one who slept on farms wanted to bring this type of hammock.

Only 77 (25.6%) respondents wanted to bring any type of bed net to their sleeping sites. Treated single net, and single soft and double soft LLINs were preferred types among respondents who slept in the forest (22; 40.7%, 14; 25.9% and 11; 20.4%, respectively), whereas double soft LLINs were preferred by respondents sleeping on farms (19; 82.6%). None of the respondents wanted to bring hard LLINs to sleeping sites. Net usage at farm and

TABLE 3
Overall net use among forest- and farm-going study respondents while at remote area sleeping sites

Net use at sleeping sites	Forest ($n = 258$), n (%)	Farm ($n = 43$), n (%)	Total ($n = 301$), n (%)
Usually sleep under treated bed or hammock net	8 (3.1)	10 (23.3)	18 (6.0)
Usually sleep under untreated bed or hammock net	48 (18.6)	5 (11.6)	53 (17.6)
Usually sleep without any net	202 (78.3)	28 (65.1)	230 (76.4)

forest sleeping sites and net preferences are summarized in Table 4.

As part of a RAI-supported program implemented in Vietnam between 2014 and 2016, hammock nets with a separate flip cover were distributed to high-risk forest-goers. When assessing the use of RAI-provided nets, 39 of the 301 respondents reported receiving hammock nets with a separate flip cover, of which 28 (71.8%) slept in forests and 11 (28.2%) slept on farms. The majority of forest workers used their RAI hammock nets on a regular basis (18; 64.3%), whereas most of the farm workers did not use RAI hammock nets on a regular basis (7; 63.6%); however, this difference was not statistically significant (POR 3.15; 95% CI 0.78, 12.68). Of the respondents with RAI hammock nets, 19 (48.7%) liked the net, of which 18 were respondents sleeping in forests (POR = 18.00; 95% CI: 2.77, 116.90). Among all 39 respondents using RAI provided nets, the most common reasons for not liking nets were that the nets were not comfortable (11; 57.9%), were too hard (10; 52.6%), were too small (7; 36.8%), and were too short (6; 31.6%). Forest-goers were more likely to keep RAI hammock net somewhere for standby (POR 0.19; 95% CI: 0.05, 0.80) (Table 5).

Of the 301 respondents to questions on net preference, 145 reported receiving LLINs from the NMCP, of whom 125 (86.2%) slept in forests and 20 (13.8%) slept on farms. Of the respondents who had received LLINs from the NMCP, 92.4% reported they never (64; 44.1%) or rarely (70; 48.3%) used this type of net (note that these categories were exclusive and that multiple answers were not possible). There were 11 (eight forest and three farm) respondents (7.6%) who reported regular use of LLINs provided by the NMCP. No respondent reported a preference for the NMCP-provided net; the most common complaints were that the net was too hard (139; 95.9%), the holes were too big (74; 50.3%), and the net size was too small (49; 33.8%). Only 25 forest-goers (17.2%) kept

these nets for standby use. A summary of hard LLIN use among forest and farm sleepers is found in Table 6.

Of all respondents, 304 answered questions about net care. The median number of times bed nets were washed in the last year was not different for respondents sleeping in the forest (median four times, IQR three times–eight times) and on farms (median five times, IQR three times–eight times) (Mann–Whitney $U = 5,232$, $n_1 = 257$, $n_2 = 43$, $P = 0.731$ upper-tailed). There was no statistically significant difference in the median number of times respondents washed hammock nets in a year between forest-goers (median 7 times, IQR five times–10 times) and farm workers (median five times, IQR four times–eight times) (Mann–Whitney $U = 5,934.5$, $n_1 = 258$, $n_2 = 39$, $P = 0.069$ two-tailed). Relating to net care, 299 (98.4%) used detergents to wash bed nets or hammock nets. After washing, only eight (2.7%) respondents sleeping in the forest and two (0.67%) respondents sleeping on a farm dried the nets in the shade, whereas the majority of respondents sleeping at forest (250; 96.9%) and farm (41; 95.3%) sites preferred drying nets in the sun.

DISCUSSION

Current global malaria elimination strategies stress the need to ensure high coverage and universal access of available vector control measures, including LLINs, to vulnerable populations. Significantly, results from this study reveal that despite a noted high coverage of mosquito net ownership in a priority transmission area in Central Vietnam, low rates of actual net usage among high-risk individuals were recorded in this study population. User preference data from this study highlight the importance of considering the end-user acceptability of malaria prevention tools, such as insecticide-treated nets, that require proper usage and care by target populations. The study results reveal that practical considerations, including perceived comfort, ease of use, and

TABLE 4
Net and hammock preference among forest- and farm-going study respondents by sleeping site

Characteristic	Forest (n = 258), n (%)	Farm (n = 43), n (%)	Total (n = 301), n (%)	POR (95% CI)
Would like to bring bed net or hammock net to sleeping sites				
Hammock net	200 (77.5)	19 (44.2)	219 (72.8)	4.36 (2.25, 8.45)
Both net and hammock net	50 (19.4)	22 (51.2)	72 (23.%)	0.23 (0.12, 0.45)
Net	4 (1.6)	1 (2.3)	5 (1.7)	0.66 (0.10, 4.32)
Do not want	4 (1.6)	1 (2.3)	5 (1.7)	0.66 (0.10, 4.32)
Types of nets want to bring	Forest (n = 54)	Farm (n = 23)	Total (n = 77)	
Untreated single net	1 (1.9)	0 (0)	1 (1.3)	
Treated single net	22 (40.7)	0 (0)	22 (28.6)	
Treated double net	4 (7.4)	3 (13.0)	7 (9.1)	0.53 (0.12, 2.36)
Single polyester (soft) LLIN	14 (25.9)	1 (4.4)	15 (19.5)	7.7 (1.33, 44.68)
Double polyester (soft) LLIN	11 (20.4)	19 (82.6)	30 (39.0)	0.05 (0.02, 0.18)
Single polyethylene (hard) LLIN	0 (0)	0 (0%)	0 (0)	
Double polyethylene (hard) LLIN	0 (0%)	0 (0%)	0 (0%)	
Did not answer the question	2 (3.7%)	0 (0%)	2 (2.6%)	
Types of hammock net want to bring	Forest (n = 250)	Farm (n = 41)	Total (n = 291)	
Hammock without net	21 (8.4)	3 (7.3%)	24 (8.2%)	1.16 (0.36, 3.78)
Hammock net with flip over	49 (19.6)	0 (0%)	49 (16.8%)	
Hammock net without zipper	2 (0.8)	2 (4.9%)	4 (1.4%)	0.16 (0.03, 0.94)
Thin hammock net with zipper	26 (10.4)	18 (43.9%)	44 (15.1%)	0.15 (0.07, 0.31)
Thick hammock net with zipper	138 (55.2)	17 (41.5%)	155 (53.3%)	1.74 (0.90, 3.37)
RAI hammock net	12 (4.8)	1 (2.4%)	13 (4.5%)	2.02 (0.36, 11.33)
Did not answer the question	2 (0.8%)	0 (0%)	2 (0.7%)	

LLIN = long-lasting insecticidal net; POR = prevalence odds ratio; RAI = Regional Artemisinin-resistant Initiative.

TABLE 5
Assessment of study respondent RAI hammock net use preferences

Received hammock net with separate flip cover (RAI hammock net)	Forest (<i>n</i> = 28), <i>n</i> (%)	Farm (<i>n</i> = 11), <i>n</i> (%)	Total (<i>n</i> = 39), <i>n</i> (%)	POR (95% CI)
Use of RAI hammock net				
Regularly	18 (64.3)	4 (36.4)	22 (56.4)	3.15 (0.78, 12.68)
Sometimes	10 (35.7)	7 (63.6)	17 (43.6)	
Like RAI hammock net	18 (64.3)	1 (9.1)	19 (48.7)	18.00 (2.77, 16.90)
Reasons RAI hammock net are disliked				
The size is too small	6 (60.0)	1 (10.0)	7 (36.8)	
The length is too short	4 (40.0)	2 (20.0)	6 (31.6)	
Net too hard	3 (30.0)	7 (70.0)	10 (52.6)	
Not comfortable	6 (60.0)	5 (50.0)	11 (57.9)	
Difficult to use	2 (20.0)	1 (10.0)	3 (15.8)	
Not nice	0 (0.0)	0 (0.0)	0 (0.0)	
Others	0 (0.0)	2 (20.0)	2 (10.0)	
Other purpose to use RAI hammock net (<i>n</i> = 39), <i>n</i> (%)				
Keep somewhere for standby	7 (25)	7 (63.6)	14 (35.9)	0.19 (0.05, 0.80)
Give to someone	3 (10.7)	0 (0.0)	3 (7.7)	

POR = prevalence odds ratio; RAI = Regional Artemisinin-resistance Initiative.

usefulness, play a role in end-user uptake and drive intervention coverage.

In low-endemic settings, such as those suitable for pursuing and scaling malaria elimination initiatives, the suboptimal use of vector control measures despite high levels of coverage could undermine malaria elimination efforts. Although cost and effectiveness are important factors when planning national or regional net distribution campaigns, our study results indicate comfort and general appeal should be considered when selecting nets to reduce gaps between ownership and actual net usage. To ensure the effective and ongoing use of malaria prevention tools such as LLINs and LLHNs, identifying and considering the target population's anticipated use setting (e.g., house, forest, and/or farm) and overall preference is essential. In addition, the provision of education and guidance on the importance, proper use, and appropriate care of nets is critical.

Research from within the GMS has found that deficits in LLIN coverage have been associated with increased exposure risk in forested locations.²⁹ Data capture in this study has shown that although net ownership tends to be high (Tables 1 and 2) and the willingness to take nets to remote areas is high (Table 4), the overall net usage in these sites remains low (Table 3). Given the need to ensure the universal coverage of the limited number of available proven vector control tools

such as ITNs for optimum effect,¹² the need to consider end-user preference is essential. Results from this study noted both an indicated willingness of respondents to use nets in remote area sleeping sites and highlighted specific preferences in net types for these settings such as thick hammock nets with zippers.

Highly acceptable LLINs and LLHNs can be a part of more comprehensive forest and farm vector bite prevention package that could also include personal and spatial repellents and insecticide-treated clothing. Information captured on the willingness of survey respondents to carry acceptable hammock nets to the forest can inform the design of future interventions. Further large-scale research specific to the GMS in regard to the role of LLIN and LLHNs and their effectiveness as part of broader innovative vector control intervention packages in forest and farm settings is also required.^{5,30}

Although scaling up the targeted distribution of acceptable LLHN interventions among high-priority forest- and farm-going population groups in Vietnam would likely lead to an increase in use and coverage, it is important to ensure these interventions are carried out in conjunction with additional complimentary campaigns. Given the diversity of these high-risk remote settings, not only in regard to the physical environment but also the type of activities pursued in these

TABLE 6
Assessment of study respondent polyethylene (hard) LLIN use

Received polyethylene LLIN net	Forest (<i>n</i> = 125)	Farm (<i>n</i> = 20)	Total (<i>n</i> = 145)	POR (95% CI)
Like polyethylene net (<i>n</i> = 144), <i>n</i> (%)	0 (0.0)	0 (0.0)	0 (0.0)	
Reasons for not liking polyethylene net				
The size is too small, <i>n</i> (%)	47 (37.6)	2 (10.0)	49 (33.8)	5.42 (1.38, 21.32)
The height is too short, <i>n</i> (%)	10 (8.0)	2 (10.0)	12 (8.3)	0.78 (0.18, 3.38)
Too hard, <i>n</i> (%)	120 (96.0)	19 (95.0)	139 (95.9)	1.26 (0.20, 8.18)
Shrank after use, <i>n</i> (%)	11 (8.8)	6 (30.0)	17 (11.7)	0.23 (0.07, 0.68)
Not nice, <i>n</i> (%)	23 (18.4)	0 (0.0)	23 (15.9)	
High porosity, <i>n</i> (%)	63 (50.4)	10 (50.0)	73 (50.3)	1.02 (0.40, 2.56)
Regularly use LLINs				
Never, <i>n</i> (%)	56 (44.8)	8 (40.0)	64 (44.1)	1.22 (0.48, 3.12)
Sometimes, <i>n</i> (%)	61 (48.8)	9 (45.0)	70 (48.3)	1.17 (0.46, 2.95)
Regularly, <i>n</i> (%)	8 (6.4)	3 (15.0)	11 (7.6)	0.39 (0.10, 1.48)
Other purpose to use LLINs				
Keep somewhere for standby, <i>n</i> (%)	25 (20.0)	0 (0.0)	25 (17.2)	
Give to someone, <i>n</i> (%)	3 (2.4)	0 (0.0)	3 (2.1)	
Block window, <i>n</i> (%)	1 (0.8)	0 (0.0)	1 (0.7)	

LLIN = long-lasting insecticidal net; POR = prevalence odds ratio.

locations, and the varying cultural, sociodemographic, and education backgrounds of individuals frequenting these areas, there is likely a need to engage with specific target population groups to tailor approaches that incorporate an array of vector control and other interventions, including new personal protection methods.^{31,32} Community-level protection awareness, highlighting potential risks of asymptomatic carriage and ongoing malaria transmission, should also be emphasized to educate high-priority forest- and farm-goers of the potential to impact vulnerable members of their communities (including infants, elderly, pregnant women, and sick).

Limitations of this study included the potential to miss some respondents within the target population group, such as those sleeping in forest or forest-fringe farms, at the time of the village-based cross-sectional study. However, this limitation can be partially addressed by comparing study results with previous reports, with the stated preference for thick material hammock nets in this study being consistent with findings from other operations research activities conducted in Vietnam.³³ This study also relied on self-reported data, and is therefore prone to recall bias. Additional follow-up field-based net coverage assessments at forest and farm sleeping sites would be useful to confirm self-reported data. Further field-based studies in these areas are currently ongoing that will assist to address some of the limitations of this study.

Despite the survey being conducted in a high priority area and inclusive of several ethnic minority groups, further expanded research throughout Vietnam to identify broader geographic, sociodemographic, and cultural diversity and trends in regard to mosquito net use may be beneficial. To ensure optimal coverage rates at scale, there remains a need to determine if net preferences vary by location or population.

In line with these findings, there are current plans for a limited and targeted procurement, distribution, and evaluation of selected LLHNS to high-risk forest-goers in Vietnam. Although LLINs and LLHNS alone are unlikely to provide complete protection against malaria transmission within the GMS, the benefits of these tools as part of a more comprehensive forest- and farm-going malaria prevention package is clear. Results of this study provide useful insights into key characteristics influencing the acceptability and use of mosquito nets among hard-to-reach forest and farm-going populations in Vietnam. These findings should be used to provide guidance to select acceptable LLINs and LLHNS to increase use among high-priority population groups in Vietnam, and provide useful data for consideration to support program implementation in similar settings throughout the GMS. Awareness of the impact of user preferences on the use of LLINs and LLHNS is critical to designing appropriate distribution and education programs to maximize the impact of interventions within the GMS.

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