

Ownership, utilization, and motivations for use or non-use of bed nets among community members at risk of malaria along the Thai-Myanmar border

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Abstract

Background

With the goal for malaria elimination in Thailand set for 2024, increased coverage and utilization of bed net, especially insecticide-treated net (ITN) or long-lasting insecticidal net (LLIN) is a key strategy. This study aims to provide the necessary information about bed net ownership and utilization among the population at risk of malaria living along the Thai-Myanmar border in Tak province.

Methods

A cross-sectional study was conducted using a mixed-method approach in 331 households from 5 hamlets in the villages of the Thai-Myanmar border. The research tools included a questionnaire, bed net inspection, and semi-structured interviews. Log-binomial regression was used to explore the sociodemographic factors associated with bed net utilization. The qualitative analysis employed a thematic analysis approach.

Results

This survey found that 98.5% of households had at least one bed net per household, and 74.3% had at least one ITN/LLIN. However, only 30.8% of households reached the standard policy set by the Minister of Public Health of one ITN/LLINs per two persons. Most residents used bed net (92.1% used in the previous night and 80.9% used every day). For those using bed nets, however, 61.9% used ITNs or LLINs the night before and 53.1% used them every day. Nonetheless, the usage rates of bed nets (any type) in the previous night among children and pregnant women were high, reaching 95.3% and 90.0%, respectively. Three explanatory variables including “not stay overnight in the forest”, “preference of free bed nets”, and “sufficient numbers of bed nets to cover all sleeping spaces”, showed statistically significant association with bed net use every day. The major reasons for the regular use of bed nets in both household and the forest were to prevent mosquito biting. The reasons for not using bednets in the household were discomfort feelings from heat, perception of unnecessary due to low mosquito density, whereas the reason for not using bednets in the forest was inconvenience.

Conclusion

Despite that overall coverage and usage of bed nets was high, only one third reached the standard level specified by the policy. Overnight in the forest, the dissatisfaction with the quality of free bed nets, insufficient number of bed nets, discomfort from heat, perception of no benefits of bed nets due to low mosquito density, and inconvenience were factors influencing bed net use. Maintaining high coverage and utility rate of bed nets should be a priority for the malaria high-risk population.

Background

Based on the 2020 world malaria report, there were 87 countries and areas with ongoing malaria transmission and approximately 229 million malaria cases in 2019 [1]. Thailand reported a substantial decline (19%) in total reported cases between 2018 and 2019 [2]. Malaria in Thailand is patchy in its distribution and can be typified as 'border malaria' and 'forest malaria', with the highest transmission along international borders and in rural forested areas [3]. The western border with Myanmar has had the highest burden of malaria and has been the focus of malaria control programs for decades [3]. Motivated by the continuous decrease in malaria burden, the Thai government has declared a national malaria elimination plan intending to achieve this by the year 2024 [4].

To accomplish this goal within the time frame, a key strategy is to increase the bed net coverage and utilization, especially insecticide-treated nets (ITN) or long-lasting insecticidal nets (LLIN). The goal is to achieve 90% LLIN coverage among populations in high transmission areas (designated as A1 or A2 areas). A1 is village with reported indigenous malaria cases in current financial year and A2 is village without indigenous malaria cases for past 1–3 years [5]. Previous studies among the general population in Thailand and among the populations on the Thai-Myanmar border (Prachuap Khiri Khan Province) identified poor coverage and poor utilization of ITN/LLINs [6, 7]. However, actual coverage and utilization of bed nets as well as factors attributing to bed net use have not been investigated in this study area.

The objective of this study was to assess the ownership, accessibility, and utilization of both treated (ITNs and LLINs) and untreated bed nets in a remaining malaria transmission focus in western Thailand. A cross-sectional study was conducted and questionnaires were used to determine predictors of bed net use. The results are useful for formulating appropriate policies for the control programs and for the promotion of LLINs and long-lasting insecticide-treated hammock net (LLIHN) within the context of populations living along the malarious borders.

Methods

Study design

This is a mixed-methods cross-sectional study that included a questionnaire, an inspection form, and semi-structured interviews among selected participants. The household survey was conducted from August to October 2019.

Study site

A community-based cross-sectional survey was conducted in the areas under the International Center of Excellence for Malaria Research (ICEMR) project in Tha Song Yang District, Tak Province, northwestern Thailand (Fig. 1). Tha Song Yang is situated in the northwestern region of Tak, on the Moei River bank near the Myanmar border. The climate is tropical with an annual average temperature of 26.4°C. The rainy season is between May and October, with an average yearly rainfall of 1540 mm. The inhabitants of this

area are approximately 30% Thai and 70% ethnic minorities. Normally, there are two peaks of malaria transmission, one at the beginning of the rainy season (May-August) and the other at the end of the rainy season (October) [8]. *Plasmodium vivax* and *P. falciparum*, respectively, are the predominant species in this region, although all human malaria parasites, as well as the simian malaria species *P. knowlesi*, have been identified in this area [9]. This study was conducted in 5 hamlets including Nong Bua, and Tala Oka (Mae Usu sub-district), Suan Oi, Pha Man, and Ko Ma Nae (Tha Song Yang sub-district).

Study population, sampling and sample size

For the quantitative component of the study, households residing in the study site were randomly selected from the study villages. Out of a total of 918 households in the 5 hamlets, 335 were selected by probability proportional to hamlet size, using an online statistical calculator [10]. Most of the household members are the Karen ethnic group [11]. From each household, the questionnaire and inspection form were administered to heads of household or representatives who look after the household. For the qualitative component, 24 potential respondents including 2 community leader from each sub-district, and 4 heads of household from each hamlet were selected to participate in the semi-structured interview. Purposive sampling was used to recruit participants for this part of the research. The target participation and the potential participants were selected based on geography, age, gender, and reported bed net use (including both those who do and don't report using bed nets). Important community leaders as "gatekeepers" were consulted and engaged in order to identify and invite the participants to join this study.

Household surveys

A community-based survey was conducted to assess the ownership, accessibility, and utilization of both treated (ITNs and LLINs) and untreated bed nets using a questionnaire, inspection form, and semi-structured interviews. Respondents from 331 households in completed the interviews. In the selected households, face-to-face interviews were conducted with heads of household by a trained study team who speak and understand both Thai and Karen languages.

Data analysis and statistics

Data were extracted from the survey database and imported into the SPSS program version 22.0 [12] for analysis. Proportions (with 95% confidence intervals) were used to summarize categorical variables related to ownership, accessibility, and utilization of bed nets. Log-binomial regression was used to explore the sociodemographic factors associated with bed net utilization (1 = yes, used bed net; 0 = no, did not use). Since populations in the same household are likely to have the same pattern of either using or not using bed nets, the log-binomial regression model included a random intercept for household to account for confounding and difference in response variation within and between households. An adjusted prevalence ratio (PR) (with 95% confidence intervals [CIs]) was used to measure the strength of this association. We used log-binomial regression (calculating adjusted PRs) rather than logistic

regression (and calculating model-adjusted odds ratios) because the proportion of bed net use was high and may have resulted in misleading model adjusted odds ratios.

The qualitative analysis employed a thematic analysis approach [13]. The tentative code categories were given in the conceptual framework. Data were analyzed using thematic analysis of content to allow bringing together of similar views from different respondents together.

Results

Household-level characteristics

For the 331 households participating in the study, the majority had bamboo/wood walls (94.56%), bamboo/wood floors (82.18%), and terracotta/galvanized iron roofs (71.60%) (Fig. 2). Among them, 315 (95.17%) households were from the Karen ethnic minority, and 4.83% were Thai. Questionnaires were administered to 122 (36.86%) male and 209 (63.14%) female household heads. The mean age of the 331 respondents was 43.42 (\pm 14.03) years; 229 (69.18%) heads of households were 35 years or older. A large proportion (77.64%) of the respondents were illiterate. Over half (54.98%) of the households had a family income of \leq 2,000 Baht/month (Table 1). For the 1,423 household members who reported bed net use, 787 (55.31%) were female (Table 2). The mean age of the household members was 25.68 (\pm 20.05) years; 620 (43.57%) were 18–59 years old. For the participating household members, 186 (13.07%) of whom stayed in the forests or the field.

Table 1
Household and heads of household characteristics of
border population in Tha Song Yang district, Tak
province, Thailand

Characteristics	Total n = 331 n (%)
Wall	
Bamboo/ wood	313 (94.56)
Concrete	18 (5.44)
Floor	
Bamboo/ wood	272 (82.18)
Concrete	59 (17.82)
Roof	
Thatch	94 (28.40)
Terracotta/ galvanized iron	237 (71.60)
Sex	
Male	122 (36.86)
Female	209 (63.14)
Age (years)	
<35	102 (30.82)
≥35	229 (69.18)
Mean (± SD)	43.42 (± 14.03)
Ethnics	
Thai	16 (4.83)
Karen	315 (95.17)
Education level	
Illiterate	257 (77.64)
Literate	74 (22.36)
Family income/month (Bath)	
≤2,000	182 (54.98)
>2,000	149 (45.02)
Mean (± SD)	2630.51 (± 1321.23)

Table 2
Household member characteristics of border population in Tha Song Yang district, Tak province, Thailand

Characteristics	Total n = 1,423 n (%)
Sex	
Male	636 (44.69)
Female	787 (55.31)
Age (years)	
≤10	428 (30.08)
11–17	263 (18.48)
18–59	620 (43.57)
≥60	112 (7.87)
Mean (± SD)	25.68 (± 20.05)
Household member stay overnight outside in the forest or the field	
Yes	186 (13.07)
No	1,237 (86.93)

Bed net ownership, access, and utilization

Table 3 shows the household-level bed net ownership, access, and utilization. Almost all (98.49%) households had at least one bed net per household, and 74.32% had at least one ITNs/LLINs in the household. However, only 30.82% of all households had sufficient numbers of ITN/LLINs, as per standard policy i.e., one ITN/LLIN per two persons. Moreover, only 4.30% of forest goers had owned LLIHNs. Besides, 86.10% of the households had sufficient numbers of bed net to cover all sleeping spaces. Although 94.17% of the household members slept in the sleeping spaces with any type of bed nets, 63.46% slept in sleeping spaces with ITNs or LLINs.

Table 3
Household ownership access and utilization of bed nets among border population
in Tha Song Yang district, Tak province, Thailand

Characteristics	n (%)
Household ownership of bed nets	
At least one net per household (any type)	326 (98.49)
At least one ITN/LLIN per household	246 (74.32)
Access of bed nets	
One net per two people (any type)	168 (50.76)
One ITN/LLIN per two people	102 (30.82)
One LLIHN per one people	8 (4.30)
% of population with access to any bed net	1,340 (94.17)
% of population with access to ITN/LLIN	903 (63.46)
% of household have sufficient numbers of bed net to cover all sleeping spaces	285 (86.10)
Utilization of bed nets	
% of population slept under any bed net last night	1,311 (92.13)
% of population slept under an ITN/LLIN last night	881 (61.91)
% of forest goers slept under an ITN/LLIN last night	122 (65.59)
% of population slept under any bed net every day	1,151 (80.89)
% of population slept under an ITN/LLIN every day	756 (53.13)
% of forest goers slept under an ITN/LLIN every day	16 (8.60)
% of children under 10 years slept under any bed net last night	408 (95.33)
% of children under 10 years slept under an ITN/LLIN last night	255 (59.58)
% of pregnant women slept under any bed net last night	10 (100.00)
% of pregnant women slept under an ITN/LLIN last night	9 (90.00)

Most of the household members (92.13%) reported using bed nets in the previous night, and 881 (61.91%) used ITNs or LLINs (Table 3). Since some respondents did not use bed net every day, especially in the summer season or when staying overnight in the forests or agricultural fields, daily use of bed net was also recorded. While 1,151 (80.89%) household members reported bed net usage every day, 756

(53.13%) used ITNs or LLINs. Only 8.60% of forest goers use ITN/LLIN every day. For children under 10 years (n = 428), 95.33% slept under a bed net in the previous night, and 59.58% slept under an ITN/LLIN. Among the pregnant women (n = 10), this was 100.00% and 90.00%, respectively. Out of all 601 inspected bed nets, 109 (18.14%) had holes (defined as a tear or opening that a finger could fit through.).

The most common pattern of bed net deployment by the household heads included inspecting for holes (86.32%) and checking for mosquitos trapped inside (83.06%). However, only 36.81% tucked in the nets fully before sleeping, and 28.99% slept away from the edges of the bed. Only 103 (33.55%) of the household heads deployed the bed nets properly (Table 4).

Table 4
Pattern of deployment of bed net by head of household owning and using bed net (n = 307)

	n	%
Pattern of deployment of bed nets ^a		
Tucking in fully during sleeping	113	36.81
Inspecting for holes	265	86.32
Checking for mosquitos trapped inside	255	83.06
Sleeping away from the edge of the bed	89	28.99
Head of household deployed bed net properly		
Yes	103	33.55
No	204	66.45
Total	307	100.00
^a Multiple responds allowed		

Sociodemographic factors associated with bed nets usage

Univariate log-binomial regressions were used to compare the daily bed nets use across the different variables. Based on the univariate models, stronger associations were found between bed net use and variables such as “stay overnight in the forest or the field” [no vs yes: PR = 6.26, 95% CI = 4.14–9.46; p < 0.001], “like to use free bed net” [yes or indifferent vs not like: PR = 1.81, 95% CI = 1.19–2.75; p = 0.006], sufficient numbers of bed net to cover all sleeping spaces [yes vs no: PR = 1.60, 95% CI = 1.24–2.06; p < 0.001], sleeping pattern based on gender [female sleep with female vs male sleep alone: PR = 1.56, 95% CI = 1.07–2.27; p = 0.021], and age [18–59 vs ≤ 10: PR = 0.74, 95% CI = 0.61–0.89; p = 0.001]. Additionally, a weak association was found between daily bed net use and marital status [others vs married: PR = 1.26,

95% CI = 1.07–1.48; $p = 0.005$], sex [female vs male: PR = 1.23, 95% CI = 1.05–1.44; $p = 0.012$], and sleeping pattern based on age (≤ 10 year) [sleep with child vs not sleep with child: PR = 1.20, 95% CI = 1.02–1.41; $p = 0.03$].

In the final multivariable log-binomial regression, all three explanatory variables including “not stay overnight in the forest or the field”, “like to use free bed nets”, and “sufficient numbers of bed net to cover all sleeping spaces” showed a significant association with daily bed net use (Table 5).

Table 5

Variables related to use of bed nets every day among respondents living in households owning at least one net (n = 1,401)

	n (%)	Univariate analysis		Multivariable analysis	
		PR (95%CI)	p-value	PR (95%CI)	p-value
Age of household member (years)					
≤ 10 (n = 418)	405 (96.89)	1	-	-	-
11–17 (n = 259)	220 (84.94)	0.87 (0.70–1.01)	0.237	0.91 (0.68–1.20)	0.490
18–59 (n = 613)	442 (72.10)	0.74 (0.61–0.89)	0.001*	0.84 (0.58–1.22)	0.367
≥ 60 (n = 111)	84 (75.68)	0.76 (0.56–1.05)	0.093	0.94 (0.60–1.46)	0.773
Sex of household member					
Male (n = 625)	456 (72.96)	1	-	-	-
Female (n = 776)	695 (89.56)	1.23 (1.05–1.43)	0.012*	1.07 (0.88–1.31)	0.501
Marital status of household member					
Married (n = 610)	439 (71.97)	1	-	-	-
Others (n = 791)	712 (90.01)	1.26 (1.07–1.48)	0.005*	0.91 (0.64–1.28)	0.570
Household member stay overnight outside in the forest or the field					
Yes (n = 184)	27 (14.67)	1	-	-	-

*p-value < 0.05, **p-value < 0.001

	n (%)	Univariate analysis		Multivariable analysis	
		PR (95%CI)	p-value	PR (95%CI)	p-value
No (n = 1,217)	1,124 (92.36)	6.26 (4.14–9.46)	< 0.001**	5.77 (3.76–8.85)	< 0.001**
Head of household like to use free bed net					
Not like (n = 75)	34 (45.33)	1	-	-	-
Yes or indifferent (n = 1,326)	1,117 (84.24)	1.81 (1.19–2.75)	0.006*	1.65 (1.07–2.55)	0.025*
Sufficient numbers of bed net to cover all sleeping spaces in household					
No (n = 190)	104 (54.74)	1	-	-	-
Yes (n = 1,211)	1047 (86.46)	1.81 (1.19–2.75)*	< 0.001**	1.65 (1.06–2.55)*	0.032**
Sleeping pattern based on gender					
Male sleep alone (n = 98)	61 (62.24)	1	-	-	-
Female sleep alone (n = 75)	63 (84)	1.35 (0.85–2.15)	0.201	1.11 (0.67–1.86)	0.683
Male sleep with female (spouse) (n = 162)	104 (64.20)	1.04 (0.70–1.56)	0.845	1.09 (0.69–1.73)	0.719
Male sleep with male (≥ 2 person/sleeping space) (n = 57)	43 (75.44)	1.24 (0.75–2.07)	0.402	1.14 (0.66–1.95)	0.646
Male sleep with female (not spouse) (≥ 2 person/sleeping space) (n = 808)	687 (85.02)	1.397 (0.99–1.96)	0.052	1.26 (0.83–1.91)	0.287
*p-value < 0.05, **p-value < 0.001					

	n (%)	Univariate analysis		Multivariable analysis	
		PR (95%CI)	p-value	PR (95%CI)	p-value
Female sleep with female (≥ 2 person/sleeping space) (n = 201)	193 (96.02)	1.56 (1.07–2.27)	0.021*	1.25 (0.79–1.99)	0.341
Sleeping pattern based on age (≤ 10 year)					
Not sleep with child ≤ 10 year (n = 533)	394 (73.92)	1	-	-	-
Sleep with child ≤ 10 year (n = 868)	757 (87.21)	1.20 (1.02–1.41)	0.030*	0.96 (0.72–1.27)	0.753
*p-value < 0.05, **p-value < 0.001					

Log-binomial regression was also used to compare the bed net use among respondents who stayed overnight outside the house in the previous year, but only family income showed a significant association with daily bed net use in the final multivariable log-binomial regression (data not tabulated).

Reasons for use or non-use of bed nets in the household and the forest

A total of 22 respondents were interviewed by semi-structured interview. The results organized into key themes that emerged from the discussions.

Reasons for use of bed nets in the household

Most participants reported using bed nets to prevent mosquito bites and malaria infection. Most of them remembered using bed nets from a very young age, whereas some of them started to use bed nets when they had children or grandchildren. Bed net use had become a habit for them and they could not sleep without it.

“I use bed nets to protect myself against mosquito bites. I have used bed nets since I was born and becoming my habit I cannot sleep without the net” (Female villager, Mae Usu subdistrict)

Additionally, free bed net distribution campaigns were mentioned as a factor that supported them to start and continue using bed nets in the last 20–30 years.

“After I immigrated to Thailand 20 years ago, I started to use bed nets and they were free bed nets distributed from health providers. The net is good and prevents mosquitoes from biting and not getting

sick with malaria.” (Female villager, Tha Song Yang subdistrict)

Bed net use in farms and forests

Forest goers in this area had not used any kinds of bed net while they were in the forest. Most forest goers used bed net only in the subsistence farm huts, their temporary residence nearby the forest. Both forest goers and farmers, if they had sufficient bed nets for use in their households, they would take the old bed nets for use in the subsistence farm huts. If they had limited bed nets, they would carry bed net to the subsistence farm hut and carry it back home, especially when children accompanied them to the farms. However, many of them used bed nets in a subsistence farm hut only in the rainy season when mosquitoes are abundant.

“When children accompanied us to the farm plots or forest, we always carried bed net to use in the farm hut. Our children need to get protection from mosquito bites.” (Female villager, Mae Usu subdistrict)

“I sleep under bed net every day. And even when I was going to overnight in the farm, I took an old bed net to use in the farm hut.” (Male villager, Tha Song Yang subdistrict)

Reasons for non-use of bed nets in the household

The major reason that participants reported for not using bed nets every day at home was discomfort from the heat and perception of unnecessary due to low mosquito density, especially in the hot season.

“I am still afraid of malaria, but I could not sleep it was too hot to sleep under the nets in the summer” (Female villager, Tha Song Yang subdistrict)

The second most commonly reported reason was feeling complacent and not wanting to expend the effort needed to set up and use nets in the evenings, especially for adolescents who did not share sleeping space with their parents.

“My son and daughter rarely use bed net because they are so lazy to hang the bed net up. I sometimes have to hang it for them and tell them to sleep under bed net.” (Female villager, Mae Usu subdistrict)

Other reasons mentioned for not using a net at home included inadequate number of bed nets, being not habitual of sleeping under the bed nets, use of alternative mosquito control methods, too small size of the free bed net, rough texture of material of free bed nets, strong smell of insecticide, and inadequate space to hang a bed net.

Reasons for non-use of bed nets in the forest or farms

The major reason for the non-use of bed nets in the forest was inconvenient to carry the bed nets and prioritized other essential items. Even in the subsistence farm hut, some felt lazy to unpack and hang the bed nets up before sleeping in. Although someone received an LLIN to use in the forest, they tried to use the hammocks in the forest, they found problems from using the net.

“Going to forest, we travel light with a few necessary items so we can carry lots forest products when we return. It is inconvenient to bring the net to the forest, it takes space to carry. It also can get entangled with other items, obstructed hunting and gatering process, in particular to hunting we need to be quick to shoot the targets. Sometime at night, animals such as elephants approach our sleeping area, we have to run away, we have no time to pack the net.” (Male villager, Tha Song Yang subdistrict)

The second reason was the inadequate number of the nets for use when visiting the forest. Other reasons for not using a net in the forest included being not habitual of sleeping under the bed nets, discomfort from heat, and use of alternative mosquito control methods.

Discussion

This is the first cross-sectional study assessing the ownership and utilization of bed nets among the border population in Tha Song Yang District of western Thailand. The results of this study revealed that the ownership of bed nets is very high (98.49%), while 246 (74.32%) had at least one treated nets. Bed nets are highly available in these localities, a result of efforts by the Department of disease control and other partners (such as non-governmental organizations) that have distributed free LLINs from the Global Fund [6]. The results are consistent with the finding of the Mobile and Migrant Population Survey in Thailand [6], which found that households with any nets were 94% in 2017, whereas households with at least one ITN were 39%. Also, Kitidamrongsuk et al [7], reported that almost all households (92.9%) in Prachuab Khiri Khan, Thailand had at least one mosquito net, whereas 41.1% of households owned at least one ITN/LLIN. Similar studies in Myanmar showed high coverage of bed nets among households of Kachin Special Region II population [14], and 50–65% coverage of ITN/LLIN among households of migrant population [15, 16]. The WHO advocates for universal coverage of ITN/LLINs with one net for every 2 persons [17]. In spite of the high-level ownership of and access to bed nets in this study because of the LLIN distribution campaign, only 30.82% of all households had sufficient numbers of ITN/LLIN for one ITN/ LLINs per two persons. This insufficiency might be due to the operational challenges of the LLIN distribution system, as some studies identified operational barriers to continuous LLIN distribution [18, 19]. This study suggests that the insufficiency of ITN/LLIN is also a concern and can be used as an indicator for the LLIN distribution program. Plucinski et al. reported that the access indicators of LLINs were high in Mozambique when the bed net distribution campaigns used a novel distribution model and used LLINs designated for each sleeping space [20]. Thus, the LLIN distribution systems in Thailand should be evaluated in the future.

Globally, malaria-related morbidity and mortality are highest in children and pregnant women [21]. Most children in this study used bed net in the previous night (95.3%). Overall bed net usage among adults was lower than among children. This was mainly due to the high focus on vulnerable age groups. However, only 59.58% of the children used ITNs/LLINs. This result is consistent with the previous findings in Myanmar and some countries in Africa [6, 15, 16, 22–26], which showed that the utilization of ITN remained moderate or low among children. However, it differs from the previous reports of high use rate of ITNs/LLINs among children [14, 27, 28]. Pregnant women, particularly primigravidas with malaria, have

a high risk of severe malaria and low birth weights [29, 30]. This study showed a high rate of ITN/LLIN use among pregnant women (90.00%). However, in many parts of the world, ITN usage remained moderate or low among pregnant women [6, 16, 22, 23, 28, 31].

One of the major factors in not using bed nets in our data was the use of different sleeping sites. Work and evening activities in the forest impact where community members choose to sleep on any particular evening. Together with the previous findings in Prachuab Khiri Khan province [7] and Southern Thailand [32], sleeping elsewhere especially at temporary shelters in the plantation is another non-use reason.

Another major factor in bed net use was net manufacturing materials and size are other factors affecting net utilization among households with more family members [7]. Many other studies reported under usage of nets due to the lack of sufficient nets to cover all household members [7, 15, 26, 27, 33–35]. Household socio-economic status has likewise been shown to influence bed net access and is the strongest determinant of net use [28, 36–43]. Our study showed that wealthier families were significantly more likely to use bed nets every day than the poorer families, likely because of the ability to purchase bed nets for use outside the home.

Consistent with previous studies [44–47], the perceived role of bed nets as a means to protect against mosquitoes and malaria was a significant predictor of seasonal bed net use. In our research, participants reported higher bed net usage during the rainy season. Aside from malaria prevention, the main reason for sleeping under nets was because they provided comfortable sleep and protected against biting insects (including mosquitoes).

Other reasons for the not using bed nets were in line with other research [7, 16, 48–57] suggesting that discomfort from heat and low mosquito density are common reasons for non-adherence. Complacency, the inadequate number of of bed net, rough materials of bed net, not having a routine of bed net use, use of alternative mosquito control methods, and too small size of free bed nets were the other most commonly cited reasons for not using a net at home. Some studies have shown that bed nets decrease airflow, making it feel hot and stifling under a net [48, 58, 59]. In seasons of low and/or variable mosquito nuisance, education will need to emphasize that the risk of malaria is not necessarily diminished when mosquito numbers are perceived to be low.

The reasons for not using bed net in the forest were also consistent with some past studies in the greater Mekong subregion [60–62]. Some forest-goers described the inconvenience of carrying bed nets, while others found inadequacy of nets for use when visiting the forest. This study suggests that the campaign of LLIN distribution appeared not effective for malaria prevention among forest goers. The advantages of these nets might be not adequately promoted. Other strategies to address outdoor transmission may need to be considered among this population [63–65].

Previously reported limited effectiveness of bed nets in Southeast Asia may have resulted from the vector feeding behavior and human activities that in some circumstances increase human-vector contacts [66, 67]. Some main malaria vectors such as *Anopheles minimus*, *Anopheles maculatus* and *Anopheles dirus*

feed outdoors at dusk between 6 and 7 p.m. when people are not in bed [66, 68]. Also, forest goers exhibit behaviors (hunting or fishing) that reduce the protection of ITNs at peak biting times [69, 70]. Despite high coverage and utilization of bed nets in this study, the bed net use behavior of people may also affect the effectiveness of bed nets. Some did not use bed net every day, especially in summers and when they stayed overnight in the forest or the field. Some did not deploy bed nets properly, used damaged/torn nets, and used untreated nets. Nevertheless, given the broader impacts of ITNs for preventing all vector-borne diseases such as malaria [71, 72], Japanese encephalitis [73], and leishmaniasis [74], proper net distribution and encouraged use still need to be strengthened, especially for the high-risk populations such as the forest goers.

Outdoor transmission remains the main challenge for malaria elimination program in Thailand. This transmission is influenced by human behavior, including efforts at preventing exposure to mosquito vectors. At least one study (from Tanzania) has shown that relatively modest coverage (53.13% ITNs use) in the community can lead to community-wide protection against malaria [75]. However high risk groups such as Karen ethnic groups living along the border and forest goers may not receive the same benefits of the protection. In our study, low use of bed nets when overnighing in the forest was related to perceptions of inconvenience of carrying and using bed nets, insufficient numbers of bed nets to use outside the home, and low perception of bed net necessity. Therefore, interventions among these high risk groups should pay attention to factors beyond bed net coverage, and use and look for long-lasting new tools or approaches for preventing exposure to mosquito vectors to decrease outdoor malaria transmission.

Study limitations included 63.14% of heads of households were female. However, female heads of households should be in better position to respond about ownership and use of bed nets of every household member. This study was conducted in Thasongyang district; therefore, the results could represent population living along Thai-Myanmar border and Karen ethnic groups, but not represent Karen groups from other areas in which lifestyle, culture, or health operation were different. Due to the limitation of budget and time, this study was conducted in one season (rainy season with more abundant of mosquitoes) which may result in high rate of bed net use in the previous night. Nonetheless, adding question of everyday use of bed net, should reduce the bias from season differences.

Conclusions

This study showed that high overall coverage and usage of bed nets in the study area; however, only one third reached the standard level specified by the policy. Overnighing in the forest or the farm plots, the dissatisfaction with the quality of free bed nets, insufficient number of bed nets, discomfort from heat, perception of no benefits of bed nets due to low mosquito density, and inconvenience were factors influencing bed net use. Moreover, only one third of heads of households deployed bed net properly. Further health promotion programs should ensure to maintain high coverage and utility rate of bed nets and further studies should prioritize the investigation of new preventive tools for effective outdoor protection in particualt ot the forest goers.

Abbreviations

ITN: insecticide-treated net; LLIN: long-lasting insecticidal net; LLIHN: long-lasting insecticide-treated hammock net; ICEMR: International Center of Excellence for Malaria Research; PR: prevalence ratio; CI: confidence interval.

Declarations

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Authors' contributions

KP, SP, and PS conceived and designed the study. KP and SP collected data and conducted interviews. KP and SL participated in sample processing and data analysis. KP, DMP, NM, SL, PS, JS, LC, and SP participated in data analysis, interpretation, and drafting the manuscript. All authors read and approved the final manuscript.

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Availability of data

The datasets used and/or analysed during the current study are not provided.

Ethics approval and consent to participate

The heads of households or adult representatives were approached for consenting before recruitment. A written informed consent was obtained as permission to conduct data collection. The study was approved by the Ethics Committee of the Faculty of Tropical Medicine, Mahidol University, Thailand (Ethical number MUTM 2019-056-01).

Consent for publication

All authors gave the consent for this publication.

Competing interests

The authors declare that they have no competing interests.

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Figures

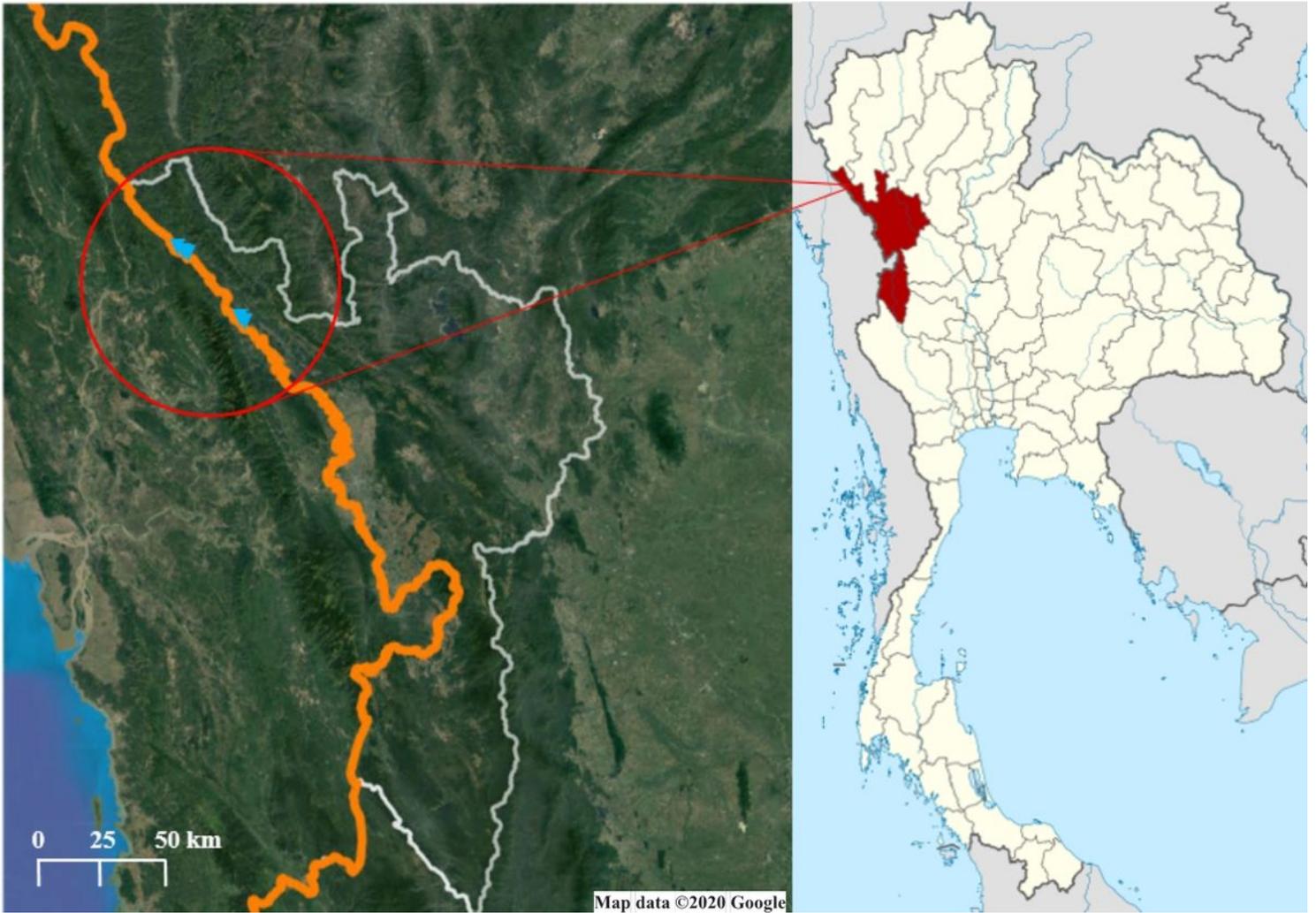


Figure 1

The study site: Tha Song Yang district, Tak province, Thailand [76] [77]. Note: The designations employed and the presentation of the material on this map do not imply the expression of any opinion whatsoever on the part of Research Square concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries. This map has been provided by the authors.



Figure 2

