Original Article

Long Lasting Insecticide-Treated Net Use of People Living in Myawaddy, a High Malaria Endemic District along Thai Myanmar Border

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Background: Myanmar accounts for the greatest number of malaria cases among the Greater Mekong Sub-regions and 60% of the total populations are residing in malaria endemic area. The Myanmar National Malaria Strategic Plan (2016 to 2020) has recommended universal coverage and use of long-lasting insecticide-treated net (LLIN) as a key vector control measure in all malaria transmission areas.

Objective: The present study aimed to identify LLIN use and associated factors in the high, moderate, and low transmission areas of Myawaddy District, which is a high malaria morbidity and mortality area.

Materials and Methods: A cross sectional study using multistage stratified sampling was performed on 423 households in the high, moderate, and low malaria transmission areas of Myawaddy District. Structured interviews and observations of LLIN use were conducted between April and May 2017. Bivariate and multivariate logistic regressions were performed to find predictors of effective LLIN use the night before the survey.

Results: Household ownership of at least one LLIN was 91.0%, 87.2%, and 96.5% in high, moderate, and low transmission areas, respectively. Among these households, those in which all household members sleeping under effective LLIN the night before the survey was lowest in high transmission area (37.8%), followed by moderate transmission area (72.4%), and low transmission area (83.8%). Knowledge of malaria was poor in high and moderate transmission areas, while perceptions towards malaria and receiving malaria information were lowest in high transmission area. Multivariate analysis showed that knowledge of malaria, perceived susceptibility and seriousness on malaria, exposure to malaria information, ethnicity of household head, family size, and number of LLIN available in the household were the important predictors of the household in which all household members sleeping under LLIN the night before the survey.

Conclusion: The present study indicated that 100% use of LLIN should be achieved through effective behavioral change communication to improve malaria knowledge and perceptions. Moreover, the National Malaria Control Program should focus on households with Kayin ethnicity, low income, and large family size in high malaria transmission area.

Keywords: Long lasting Insecticide-treated net, Malaria, Thai Myanmar Border

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Malaria remains a major threat in public health around the world[1]. Nearly 3.2 billion people are living in malaria endemic area, and 91 countries and territories around the world had ongoing malaria transmission in 2015[1]. The World Health Organization (WHO) estimated that there were 214 million cases of malaria worldwide and approximately 438,000 deaths from malaria in 2015. Although number of malaria cases had fallen by 18% between 2000 and 2015, one of the major threats to control effort against malaria is emergence of artemisinin-resistant malaria in the Greater Mekong countries[1]. The core intervention package recommended by WHO for control and prevention of malaria to reduce mortality and morbidity includes vector control,

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diagnosis and treatment, and chemoprevention[2]. Around 6.2 million lives have been saved by scaling up of malaria intervention between 2000 and 2015[3]. It is clearly identified that the use of insecticide-treated nets (ITNs) reduce malaria morbidity and mortality[4]. The WHO Global Malaria Program (GMP) recommendation described a shift in guidance on prevention of malaria through the use of ITNs and recommended to achieve universal coverage with long lasting insecticide-treated net (LLIN) in high-risk group of population[5]. The core global malaria prevention interventions include LLIN and indoor residual spraying (IRS), which showed impact in reducing malaria mortality[4,6]. Despite current malaria control efforts, the disease still causes a significant burden around the world.

Myanmar has the greatest malaria burden among the Greater Mekong Sub-regions and over 70% of incidence cases are reported from Myanmar. Approximately 60% of the population are living in malaria endemic area[7]. Furthermore, malaria is still a public health concern in Myanmar due to population movement, economic development activities, and occurrence of multi-drug resistant malaria[7]. WHO reported that nearly 152,195 confirmed malaria cases occurred in Myanmar and 75% of all cases were infected by *Plasmodium falciparum*[1]. In the past years, both malaria cases and death have been decreasing in high malaria endemic area[7]. However, emergence of multi-drug resistance malaria in the southern part of Myanmar, bordering Thailand, has been found, and this may cause challenges toward malaria elimination in Myanmar[8].

Myanmar is trying to scale up its malaria control interventions to decrease the high burden of malaria aiming to achieve malaria elimination by 2030, which is *P. falciparum* malaria by 2025 and *Plasmodium vivax* malaria by 2030[7]. In line with the objectives, 80% of people must be protected by LLIN. However, due to emergence of artemisinin-resistant malaria, it was recommended that 100% coverage of use of LLIN be achieved in all transmission areas[7]. The National Malaria Control Program (NMCP) and implementing partners delivered over eight million of LLINs free of charge in all malaria risk areas between 2001 and 2014[7].

Malaria prevention control in cross border is more difficult compared to central area and non-border area, because of mountainous, forested, population movement across the border, and inaccessible terrain[9]. Myawaddy District is located in the South Eastern part of Myanmar on the Thai Myanmar border and has high malaria morbidity. According to areas zonation by the Global plan for Artemisinin Resistance Containment (GPARC), Myawaddy District is situated in Tier 1, area credible of artemisinin-resistant malaria[7]. Although the Myanmar National Malaria Strategic Plan (2016 to 2020) recommend universal coverage of LLIN as a key vector control measure in all malaria transmission areas, the use of LLIN is not well studied in Myawaddy District along Thai Myanmar border. Study on different transmission areas is essential to provide priority for malaria intervention programs. The present study aimed to explore LLIN use and factors influencing LLIN use in high, moderate, and low malaria transmission areas in Myawaddy District. The findings and recommendations of the study will give a way toward malaria elimination strategies to government and policy makers for malaria elimination in Myanmar by 2030.

Materials and Methods

Study setting

The study was conducted in rural malaria endemic area of Myawaddy District, Kayin State, which is located on geographic coordinates of 16° 30′ N latitude and 98° 25′ E longitude in the Southeastern part of Myanmar, bordering with Thailand. It shares boundaries with Hlaing Bwe township to the North, Thailand to the East, Kawkareik township to the West and Kyar Inn Seikyi township to the South. The district is about 3,140.5 km² and the population is estimated at 210,540, among which 116,580 people live in urban area and 93,960 people live in rural area (projected population from the 2014 national population census). The population is mixed of Kayin and Burmese ethnic people. Most of Kayin ethnic people live in hard to reach area and their major occupation is farming, agriculture, and forest related works. Most Burmese people are migrant coming from other parts of the country for working across the border. Myawaddy District has 62 villages in rural area and five wards in urban area. Some villages are under the control of non-state actor and there is limited security. According to village-level malaria micro stratification by the NMCP based on annual parasite incidence (API), the rural area can be divided in to high, moderate, and low malaria transmission area as follow, high transmission area (API greater than 5) 27 villages, moderate transmission area (API 1 to 5) 25 villages, and low transmission area (API 0 to 1) 10 villages. There is no malaria transmission in the urban area.

Sample size and sampling procedure

The study was a community-based cross-sectional survey conducted by using structured questionnaire to interview the head of the household who was 18 years or older in Myawaddy District. Assuming expected knowledge about malaria and LLIN utilization to be 50% and a desired precision of 5%, the sample size was calculated by the formula ($Z^2 \times P(1–P) / d^2$) to be 380. After adding 10% of non-respondent rate, total sample size was 423.

Multistage stratified sampling was applied to get the appropriate sample from three malaria transmission areas of Myawaddy District, namely, high malaria transmission area, moderate malaria transmission area, and low malaria transmission area. Sixty-two villages in Myawaddy Township were included. Among the 62 villages, 27 villages were situated in high malaria transmission areas, 25 villages in moderate malaria transmission area, and 10 villages in low malaria transmission area according to malaria micro stratification by the NMCP. From each malaria transmission area, three villages were randomly selected. Then 47 households from each village were selected by simple random sampling. At each household, the head of the household was selected for the interview. Four hundred twenty-three respondents were recruited in the present study.

Instruments

The questionnaire was adapted from instruments developed by the WHO Malaria Indicator Survey (MIS)[10] and Roll Back Malaria behavioral change communication[11]. After validation from three malaria experts, two from the Ministry of Public Health, Thailand and one from Myanmar, the questionnaire was tested with 30 respondents in a village that was not part of study area.

The outcome variable, sleeping under effective LLIN, was defined as household with all household members sleeping under LLIN the night before the survey. Effective LLIN means the LLIN was in good condition and not expired. Theoretical model of the study was based on health belief model (HBM). The dependent variables were socio-demographic characteristic, knowledge about malaria, perceived susceptibility on malaria, perceived seriousness of malaria, perceived benefit of malaria intervention, perceived barrier toward malaria prevention, and household head receiving malaria information within one year. The level of knowledge about malaria was calculated based on the number of correct answers. If the respondent could answer one question correctly, they got 1 score and the range of scores was 37 to 0. The level of the knowledge was classified into two types. Those who got the score equal or above the mean plus standard deviation were categorized as high-level of knowledge on malaria and the rest were low. Regarding perception toward malaria, the answer was “Agree”, “Unsure” and “Disagree” according to Likert scale[12]. The scores were 3, 2, 1 on Agree, Unsure, and Disagree for positive question and reversed for negative ones, respectively. For the classification of score, levels were classified into high and low. In each part of level, those who got the score equal or above the mean plus standard deviation were categorized as high perception and the rest were low perception. The reliability test result for knowledge about malaria (α=0.80) and perceived toward malaria (α=0.69) was assessed by Cronbach’s alpha.

Data collection

Data were collected by one researcher and three interviewers who were trained for one day regarding to the objectives of the study, contents of questionnaires, procedure, and practice in real condition. After getting ethical approval, the researcher and interviewers went to sampled household and interviewed the head of household. Data collection were carried out in early morning around 8 am to 10 am between April and May 2017. The interviewers directly observed total number of LLIN and cross-checked LLIN use with the interview response of household head in the morning of data collection day as well as verified that LLIN were actually used the previous night by checking that LLIN were hanged or folded on the bed. They also checked to confirm that total numbers of effective LLINs matched with family members. The condition of LLIN and expiry date were checked by interviewers. In the present study, number of LLIN and use from cross check by observation were consistent with interview response of household head in all household.

Data management and analysis

Firstly, the data of the study was entered in Microsoft Excel database and cleaned to be completed and accurate. SPSS version 21.0 was used for statistical data analysis. Frequency, percentage, median, mean, and standard deviation was used for description of some variables. Bivariate logistic regression was applied to determine the association between each independent variable with LLIN use. Finally, the factors with significant p-value of less than 0.05 in bivariate analysis were analyzed by

multivariate logistic regressions to examine significant predictors for household in which all household members sleeping under LLIN. A p-value of less than 0.05 in multivariate logistic regression was taken as statistically significant.

Ethical approval

The ethical approval was obtained from the Ethical Review Committee of Mahidol University (MUSSIRB-2017/086). Before starting the study, the objectives and purpose of the study were explained to representatives of township health department, other concerned authorities, and all the respondents. The participants were explained about objectives and purpose of the study before the interview. Written informed consents were obtained from all participants prior to the study. The participants had the right to accept or refuse to participate in the study.

Results

Basic socio-demographic characteristic of household

Four hundred twenty-three households resided by 1,907 people participated in the survey with a 100% response rate. Age of respondent ranged from 20 to 67 years with the mean age of 42 (SD 12.0). Most of household heads were male and married in all study areas. All household heads in high malaria transmission area were Kayin ethnic people, while most of the respondents in moderate and low transmission areas were Burmese. Majority of household head in high transmission area had no formal education (49.6%) compared to moderate (18.4%) and low transmission areas (10.6%). The largest proportion of household head in high malaria transmission area were farmers and forest workers (96.5%), while almost half of household heads in moderate and low transmission area were daily workers. Regarding monthly family income, 55.1% of respondents in high transmission area earned less than 100,000 kyats. The socio-demographic characteristics of the sample are shown in Table 1.

Knowledge, perception, and information about malaria

According to knowledge on malaria regarding to cause of malaria, transmission of malaria, sign and symptom of malaria, mosquito biting time and mosquito breeding place, diagnosis, treatment, and prevention, more than half of the respondents (60.8%) had good level of knowledge, while the highest level was in low transmission area and the lowest was in high and moderate transmission areas. The study showed that the respondents in high transmission area had the lowest perception in susceptibility and severity of malaria as well as benefits of protection and treatment of malaria, while they had highest perception in barrier of malaria protection. The respondents in high transmission area also received less information about malaria, as shown in Table 2.

LLIN ownership and uses

The results revealed that among 423 households, there were 1,111 bed nets and 830 (74.7%) beds were effective LLINs. Bed net coverage was high overall, with net to person ration at 1:1.71 (more than one net for two people but LLIN coverage was low with LLIN to person ratio 1:2.22 (1 LLIN for every 2.2 people). Household with at least one effective LLIN was not much different in the three areas ranging from 90.1% in high transmission area, 87.2% in moderate transmission area, and 96.5% in low transmission area. Regarding LLIN use, of 386 households that had at least 1 LLIN, only 251 (65%) households slept under effective LLIN the night before the survey and the LLIN use was lowest in high transmission area (Table 3).

Factor associated with sleeping under LLIN the night before the survey

Bivariate logistic regression was performed to determine factors associated with household in which all household members sleeping under effective LLIN the night before the survey. Among household owning a net, 12 factors out of 18 variables were associated with household in which all household members sleeping under effective LLIN the night before data collection day($p<0.05$). Those are residence of household, race, educational status, occupational status, number of family member, family income, number of LLIN, knowledge about malaria, perceived susceptibility on malaria, perceived seriousness of malaria, perceived barrier towards malaria prevention of malaria, and receiving malaria information within one year.

The independent variables that found statistically significant ($p<0.05$) from bivariate analysis were additionally tested by multivariate analysis to find strength of association between independent variables and all household members sleeping under LLIN. The residence of household were significantly associated with effective LLIN use, where households in moderate transmission area and low transmission area were 6.4 (AOR 6.40, 95% CI 1.43 to 28.57) and 5.3 (AOR 5.35, 95% CI 1.16 to 24.56) times more likely to have all household members sleeping under effective

Table 1. Socio-demographic characteristics of the household by malaria stratum

	Total (n = 423) n (%)	High transmission area (n = 141) n (%)	Moderate transmission area (n = 141) n (%)	Low transmission area (n = 141) n (%)
Age group				
≤42 years	221 (52.2)	76 (53.9)	63 (44.7)	82 (58.1)
>42 years	202 (47.8)	65 (46.1)	78 (55.3)	42 (29.8)
Sex				
Male	313 (74.0)	111 (78.7)	100 (70.9)	102 (72.3)
Female	110 (26.0)	30 (21.3)	41 (29.1)	39 (27.7)
Marital status				
Unmarried	29 (6.9)	8 (5.7)	9 (6.4)	12 (8.5)
Married	394 (93.1)	133 (94.3)	132 (93.6)	129 (91.5)
Nationality				
Burmese	212 (50.1)	0 (0.0)	99 (70.2)	113 (80.1)
Kayin	176 (41.6)	141 (100.0)	20 (14.2)	15 (10.7)
Other	35 (8.3)	0 (0.0)	22 (15.6)	13 (9.2)
Educational level				
No education	111 (26.2)	70 (49.6)	26 (18.4)	15 (10.6)
Primary school and above	312 (73.8)	71 (50.4)	115 (81.6)	126 (89.4)
Occupation				
Farmer/forest worker	230 (54.4)	136 (96.5)	53 (37.6)	41 (29.1)
Daily worker	130 (30.7)	1 (0.7)	66 (46.8)	63 (44.7)
Own business/vendor/government staff	63 (14.9)	4 (2.8)	22 (15.6)	37 (26.2)
Family members				
1 to 5 persons	311 (73.5)	95 (67.4)	107 (75.9)	109 (77.3)
>5 persons	122 (26.5)	46 (32.6)	34 (24.1)	32 (22.7)
Family income (Kyats)				
≤100,000 kyat	233 (55.1)	124 (87.9)	67 (47.5)	42 (29.8)
>100,000 kyat	188 (44.4)	16 (11.4)	74 (52.5)	98 (69.5)
Not answer	2 (0.5)	1 (0.7)	0 (0.0)	1 (0.7)
Number of LLIN in household				
No LLIN	37 (8.7)	14 (9.9)	18 (12.8)	5 (3.6)
1 to 2 LLIN	266 (62.9)	86 (61.0)	90 (63.8)	90 (63.8)
3 to 5 LLIN	120 (28.4)	41 (29.1)	33 (23.4)	46 (32.6)

LLIN=long lasting insecticide-treated net

LLIN than those in high transmission area (p=0.015). Kayin ethnic people were less likely to sleep under LLIN than Burmese 0.28 (AOR 0.28, 95% CI 0.09 to 0.91). Household with five family members or less were 2.5 times more likely to have all household members sleeping under LLIN than those with six members and more (AOR 2.50, 95% CI 1.03 to 6.03). Additionally, households in which family income is more than 100,000 kyats were 2.5 times more likely to sleep under LLIN by all household members (AOR 2.55, 95% CI 1.09 to 5.97). Households with three or more LLIN were 2.9 times more likely to have all household members sleeping under LLIN (AOR 2.95, 95% CI 1.24 to 7.00) than those who had two

Table 2. Knowledge and perception and information about malaria

	Total (n = 423) n (%)	High transmission area (n = 141) n (%)	Moderate transmission area (n = 141) n (%)	Low transmission area (n = 141) n (%)
Knowledge about malaria				
High (27 to 36)	257 (60.8)	72 (51.1)	70 (49.6)	115 (81.6)
Low (14 to 26)	166 (39.2)	69 (48.9)	71 (50.4)	26 (18.4)
Mean=27.60, SD=4.52, Max=36, Min=14				
Perceived that malaria is severe				
High (17 to 18)	355 (83.9)	105 (74.5)	117 (83.0)	133 (94.3)
Low (11 to 16)	68 (16.1)	36 (25.5)	24 (17.0)	8 (5.7)
Mean=17.53, SD=0.89, Max=18, Min=11				
Perceived Benefit of protection and treatment				
High (14 to 15)	356 (84.2)	112 (79.4)	113 (80.1)	131 (92.9)
Low (9 to 13)	67 (15.8)	29 (20.6)	28 (19.9)	10 (7.1)
Mean=14.53, SD=1.05, Max=15, Min=9				
Perceived Barrier of protection				
Low (11 to 15)	280 (66.2)	64 (45.4)	101 (71.6)	115 (81.6)
High (5 to 14)	143 (33.8)	77 (54.6)	40 (28.4)	26 (18.4)
Mean=11.09, SD=2.71, Max=15, Min=9				
Receiving information about malaria				
Yes	241 (57.0)	61 (43.3)	92 (65.2)	88 (62.4)
No	182 (43.0)	80 (56.7)	49 (34.8)	53 (37.6)

SD=standard deviation

Table 3. Household LLIN ownership and utilization

	Total n (%)	High transmission area n (%)	Moderate transmission area n (%)	Low transmission area n (%)
Household net ownership (n = 423)				
HH with no bed net	6 (1.4)	3 (2.1)	1 (0.7)	2 (1.4)
HH with no LLIN	37 (8.7)	14 (9.9)	18 (12.8)	5 (3.5)
HH at least 1 LLIN	386 (91.3)	127 (90.1)	123 (87.2)	136 (96.5)
HH at least 1 LLIN for every 2 people	214 (50.6)	66 (46.8)	62 (43.9)	86 (60.9)
Household with all household members sleeping under LLIN last night (n = 386)				
LLIN use last night	251 (65.0)	48 (37.8)	89 (72.4)	116 (83.8)

HH=household; LLIN=long lasting insecticide-treated net

LLINs and less. Household heads who have high-level of malaria knowledge were 4.3 times more likely to have all household members sleeping under LLIN (AOR 4.31, 95% CI 2.03 to 9.13). Household heads who have high perceived susceptibility on malaria were 10.29 times more likely to have all household members sleeping under LLIN than those who have low level on perceived susceptibility on malaria (AOR 10.29, 95% CI 4.61 to 22.96). Moreover, household heads who have high perceived seriousness on malaria were 3.75 times more likely to have all household members sleeping under LLIN than those who have

Table 4. Association between socio-demographic characteristics and household with all household member sleeping under LLIN the night before survey

Socio-demographic factor	n = 386	LLIN used last night n (%)	Crude OR (95% CI)	p-value	Adjusted OR (95% CI)	p-value
Transmission area						
High	141	48 (37.8)	1		1	
Moderate	141	89 (72.4)	4.30 (2.52 to 7.34)	<0.001	6.4 (1.43 to 28.57)	0.015
Low	141	114 (83.8)	8.52 (4.77 to 15.23)	<0.001	5.35 (1.16 to 24.56)	0.031
Age						
≤42 years	200	137 (68.5)	1			
>42 years	186	114 (61.3)	0.73 (0.47 to 1.10)	0.138		
Sex						
Male	281	184 (65.5)	1			
Female	105	67 (63.8)	0.92 (0.58 to 1.48)	0.759		
Marital status						
Unmarried	25	12 (48.0)	1			
Married	361	239 (66.2)	2.12 (0.94 to 4.79)	0.07		
Nationality						
Burmese	199	168 (84.4)	1		1	
Kayin	156	63 (40.4)	0.33 (0.14 to 0.12)	0.01	0.28 (0.09 to 0.91)	0.035
Others	31	20 (64.5)	0.12 (0.07 to 0.20)	<0.001	0.66 (0.18 to 2.41)	0.537
Educational level						
No education	94	36 (38.3)	1		1	
Primary school and above	292	215 (73.6)	4.49 (2.75-7.34)	<0.001	1.04 (0.46 to 2.35)	0.923
Occupation						
Farmer and forest worker	199	99 (49.7)	1		1	
Daily workers	126	97 (77.0)	3.37 (2.05 to 5.56)	<0.001	1.24 (0.49 to 3.13)	0.648
Own business/vendor and government staff	61	55 (90.2)	9.25 (3.81 to 22.48)	<0.001	1.7 (0.54 to 5.32)	0.362
Number of family members						
>5 persons	102	53 (52.0)	1		1	
1 to 5 persons	284	198 (69.7)	2.12 (1.33 to 3.38)	0.001	2.50 (1.03 to 6.03)	0.041
Family income						
≤100,000 kyats	207	112 (54.1)	1		1	
>100,000 kyats	177	138 (78.0)	3.00 (1.91 to 4.70)	<0.001	2.55 (1.09 to 5.97)	0.031
Number of LLIN in household						
1 to 2 LLIN	266	160 (60.2)	1		1	
3 to 5 LLIN	120	91 (75.8)	2.07 (1.28 to 3.37)	0.003	2.95 (1.24 to 7.00)	0.014
Knowledge on malaria						
Low	143	49 (34.3)	1		1	
High	243	202 (83.1)	9.45 (5.83 to 15.29)	<0.001	4.3 (2.03 to 9.31)	<0.001
Perceived susceptibility on malaria						
Poor	109	20 (18.3)	1		1	
Good	277	231 (83.4)	22.34 (12.53 to 39.87)	<0.001	10.29 (4.61 to 22.96)	<0.001
Perceived seriousness on malaria						
Poor	51	6 (11.8)	1		1	
Good	335	245 (73.1)	20.41 (8.42 to 49.49)	<0.001	3.75 (1.23 to 11.43)	0.020
Perceived benefit of malaria protection						
Poor	58	36 (62.1)	1			
Good	328	215 (65.5)	1.16 (0.65 to 2.07)	0.609		
Perceived barrier of malaria protection						
Poor	120	49 (40.8)	1		1	
Good	266	202 (75.9)	4.57 (2.88 to 7.24)	<0.001	1.48 (0.73 to 3.02)	0.274
Receiving malaria information						
No	155	69 (44.5)	1		1	
Yes	231	182 (78.8)	4.62 (2.96 to 7.23)	<0.001	2.37 (1.19 to 4.69)	0.013

LLIN=long lasting insecticide-treated net; OR=odds ratio; CI=confidence interval

Figure 1. Misuse of LLIN in nursing plant in high transmission area.

(Photo was taken by researcher at the time of data collection on May 11, 2017)

low level on perceived severity (AOR 3.75, 95% CI 1.23 to 11.43). Finally, the present study also found that household head who had received information about malaria was associated with all household members sleeping under LLIN, whereas, household heads who had received information about malaria within one year were 2.37 times more likely to sleep under LLIN by all household members (AOR 2.37, 95% CI 1.19 to 4.69).

Discussion

In line with global malaria control and elimination program, Myanmar is trying to eliminate malaria by 2030. This requires achieving universal coverage and use of LLIN in all malaria transmission areas. The present study found that household ownership of one effective LLIN was not much different across three areas, but utilization was slightly different with lowest in high transmission area. Household with at least one LLIN for every two people was 46.8% in high transmission area and this result was fewer than recommendation by the national policy. The guideline recommends a 100% coverage of LLIN in all malaria transmission areas and one LLIN should be distributed for every two persons[7]. All the households in the present study received their LLIN from the free distribution campaign conducted by the NMCP and the INGO. Households without LLINs were either away on the day of free distribution of LLIN or they had moved from other places to Myawaddy District. Another reason may probably due to misuse of LLIN for other purposes (Figure 1). Household ownership of at least one LLIN in the present study is similar to a study in Kachin state, which shows a 90.2% availability[13], and higher than the study conducted in eastern part of Myanmar, which found that 15.5% of household in urban area and 27.3% in rural area had enough LLIN[14]. Regarding household utilization of LLIN, the present survey found that LLIN use was lowest in high transmission area (37.8%), followed by moderate transmission area (72.4%), and low transmission area (83.8%). This result indicated a higher chance of getting malaria in high transmission area due to the low use of LLIN.

In the present study, residence of the household is significantly associated with sleeping under LLIN where people living in moderate and low transmission areas were more likely to sleep under effective LLIN than in high transmission area. High prevalence of malaria could be due to low use of LLIN. Most of the respondents in high transmission area were not used to sleep under LLIN and the LLIN were used for other purposes such as nursing seed, plantation, and fishing at the time of data collection day. Similarly, comparative study conducted in high-risk and moderate-risk area of Colombia reported that moderate risk area had higher malaria preventive practices than high-risk area[15]. The study found that households in high transmission area were ethnic people, poorer, less educated, having low perception and low knowledge about malaria, and lack of receiving information about malaria compared to moderate transmission and low transmission area. Illiterate people, those with low levels of education, and ethnic minority in high transmission area might be unable to understand written Information Education and Communication (IEC) materials. Another reason might be due to geographical differences across three areas. Households in high transmission areas were remote, forested, and far away from city. Thus, transportation difficulty of LLIN lead to inadequate LLIN for all household members and low utilization.

Kayin ethnic people were less likely to sleep under LLIN than Burmese. The reason might be a general lack of malaria information and awareness among ethnic people for LLIN use. They might be unable to understand IEC materials written in Myanmar language, such as posters and pamphlets as ethnic people have limited command of the Burmese language. Another reason could be due to the traditional belief and practices of ethnic people in Myanmar. Thus, low perception and knowledge about malaria lead to low LLIN use among Kayin ethnic people.

Number of household member was negatively associated with LLIN use. This could be due to not

enough LLIN for all family members. Another reason might be due to not enough sleeping space to hang LLIN in household with large family size, even though they have an adequate number of LLIN for all family members. The current study is consistent with research conducted in Ethiopia where households with a family size of eight and above were 75% less likely to sleep in LLIN than those with one or two[16]. Similarity, another study conducted in Southwest Ethiopia reported that households with three or fewer family members were 2.2 times more likely to sleep under ITN[17].

Economic status of household affects all family members sleeping under LLIN. The reason may be due to inadequate distribution of LLIN and irregular distribution LLIN in which high income family can afford to buy LLIN for all family members. Another reason might be LLIN distribution type in Myanmar where LLIN were through distribution campaign and not continuous distribution, and damage and lost of LLIN after distribution campaign lead to inadequate LLIN for all household members. Another reason may be that poor households might not have access to radios or television, thereby missing health messages broadcast through these media for prevention of malaria. The present study's result supports the previous studies[17,18]. One research conducted in China-Myanmar-Laos border areas concluded that high income families were more likely to use ITN than low income families[18]. Further, in Ethiopia, a study found a similar result that wealthiest families were more than three time more likely to use LLIN than poorest families[17]. However, the current observation is contrary to other study carried out in Kachin, Myanmar, which concluded that poorest families were more likely to sleep in ITN[13].

In the present study, number of LLINs in household was positively associated with LLIN use, where households with three and more LLINs were more likely to use LLINs. This was because the households have not enough LLIN for all household members. This finding has been observed in studies conducted in Ethiopia[16] and Cameroon[19]. Moreover, another study carried out in Zambia also reported that households with three and more LLIN were two times more likely to sleep under LLIN[20].

A positive association was found between perceived knowledge on malaria of household head and LLIN use showing the more knowledge on malaria of a household head was, the more likely to have the house members sleeping under LLIN. This result is consistent with study conducted in Kachin and Eastern Myanmar that showed that household heads who had high malaria knowledge were more likely to sleep under ITN[13,14]. Several studies also mentioned that knowledge of respondents and ITN was positively, negatively, and not associated. Two studies in Southwest and Eastern Ethiopia were also similar with the current findings[21,22], however two studies carried out in Ghana and Nigeria concluded negatively[23,24]. The studies conducted in Cameroon and Su-Saran, Africa reported that there was no association between knowledge on malaria and ITN uses[19,25].

The authors' results also suggest that household head with higher perceived susceptibility on malaria were more likely to sleep under LLIN than those with low level. The current result was similar with one research conducted in Vietnam and concluded that perceived susceptibility on malaria was associated with ITN use[26]. However, in Taiwan the study by using HBM reported that perceived susceptibility on malaria was negatively associated with preventive practices. Thus, the current result was contrary to the study in Taiwan that respondent who had less perceived susceptibility on malaria were more likely to have good malaria preventive practices[27]. Household heads who had high perceived seriousness on malaria was positively associated with LLIN use. The current study supported the study conducted in West Bengal, India, which revealed that respondents who perceived that malaria is an important cause of morbidity and mortality were more likely to have all family members sleeping under LLIN[28]. Similarity, another study conducted in Nigeria also reported that respondents who knew malaria is dangerous and malaria can cause death were more likely to use ITN[29]. Moreover, another study by HBM reported that when it is perceived that malaria is severe, it is positively associated with preventive practices[27].

Household heads who had received malaria information within one year were more likely to have all household members sleeping under LLIN than those who had not. The reasons could be because household head who received information about malaria knew about the transmission of malaria and the effectiveness of LLIN for prevention. The current finding was in concordance with the result of study conducted in Mali and concluded that individuals who received educational component about malaria were 1.9 times more likely to use ITN than those who did not[30]. Similar findings were also found in one study in Nigeria that respondents who had exposure on mass media campaign about malaria were more likely to sleep under ITN[31]. It has also been explained in Edo state, Nigeria that respondents who had received

information about malaria were more likely to use ITN[32].

Limitation

As the study was carried out at the beginning of malaria transmission season, the finding may not reflect LLIN use in other seasons among people living in Myawaddy District. Furthermore, the use of LLIN the night before survey might not reflect continuous use. However, the present study has strength that the interviewer directly observed all the LLIN in household and checked the condition and expiry date of LLIN in early morning at the time of survey.

Conclusion

The present study indicated that knowledge and perception toward malaria and LLIN use were lowest in high transmission area. The understanding knowledge, perception regarding malaria, and LLIN use of people living in three malaria transmission areas is essential to provide priority interventions. Thus, residents in high transmission area are at higher risk of mosquito bite and acquiring malaria infection. Therefore, 100% coverage and use of LLIN should be achieved through consistent and regular distribution campaigns coupled with behavioral change communication (BCC) to improve knowledge and perception about malaria and LLIN use, focusing on high transmission area, Kayin ethnic people, low income family, and large family size.

What is already known on this topic?

The Myanmar National Malaria Strategic plan (2016 to 2020) recommend achieving 100% coverage of LLIN use in all transmission areas. Previous study in China Myanmar border reported that the percentage of household with at least one bed net was 99.7%, and 76.1% of which slept under ITNs/LLINs the night before survey. Another study in Eastern Myanmar showed that household ownership of at least one ITN was 27.3% in rural area, and 15.5% in urban area and the percentage of household in which all household members sleeping under ITN the night before survey was higher in rural area in compared to urban area (15.3% versus 6.9%). Both studies mentioned that people with high knowledge on malaria were more likely to sleep under LLIN.

What this study adds?

This study found that LLIN ownership and usage were lower than WHO recommendation and The National Malaria Strategic Plan. LLIN usage and knowledge of malaria were lowest in high transmission areas. This study provides the predictors of LLIN usage among people living in the Thai Myanmar border of malaria endemic areas.

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Ethics approval and consent to participate

Ethical approval and clearance was obtained from the Ethical Review Board of Mahidol University (certificate of approval number: MUSSIRB-2017/086). An administrative authorization was obtained from Myawaddy District Health Department. Written informed consent was obtained from the head of household prior to the interview.

Authors' contributions

Naing T, Puckpinyo A, and Peltzer K conceived and designed the study. Naing T conducted the field work. Naing T, Puckpinyo A, and Peltzer K conducted statistical analysis, data validation and management. All authors read and approved the final version of the manuscript.

Availability of data and materials

Data and materials from this study can be obtained from the first author on reasonable request.

Conflicts of interest

The authors declare no conflict of interest.

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