Received June 2018
Accepted July 2018

Effect of different border migration patterns and factors related to malaria infection in Tanintharyi Region, Myanmar: A case-control study

Soe Lin Thu and Tepanata Pumpaibool
College of Public Health Sciences, Chulalongkorn University, Bangkok, Thailand

Abstract

Purpose - The study aimed to identify migration pattern of border migrant people and the factors associated with malaria infection in Myanmar-Thailand border area in Tanintharyi region, Myanmar.

Design/methodology/approach - An unmatched case-control was conducted among 320 migrant people living in Dawei, Thayetchaung and Palaw Townships with 160 cases and 160 controls during March to May 2018. Cases and controls were confirmed by rapid diagnostic test. Data collection was done by using structure questionnaires through face to face interview. Bivariate analysis and logistic regression were performed to determine the association between migration patterns and associated factors with malaria infection.

Findings - More than half of respondents conducted inter-rural migration; and the rests were inter-municipal migration (19.4%) and inter-regional migration (27.8%). Inter-regional migration (crude OR=1.82, 95%CI=1.11-2.99), seasonal migration (crude OR=2.99, 95%CI=1.44-6.24) and non-contract migration (crude OR= 2.60, 95%CI=1.30-5.21) were risk factors for malaria at 5% significance level. Moreover, poor protective behavior (adjusted OR=8.85, 95%CI=2.82-27.80), difficult to access malaria health services (adjusted OR=34.28, 95%CI=4.37-268.48) were risk factors for malaria infection in multiple logistic regression at 95% CI.

Originality/value - Malaria risk was varied with migration status and was influenced by protective behavior and ability to access malaria health services. Local health authorities should target high risk migrant people and provide easy available of malaria health services in Myanmar-Thailand border area.

Keywords Malaria, Migration pattern, Myanmar-Thailand border area

Paper type Research paper

Introduction

Over recent years, remarkable progress has been conducted in reduction of global malaria burden but there are many challenges to reach malaria free world [1]. Nowadays, malaria did not exist as a forest-dependent disease and mainly impacted by population migration, mostly to border areas. Most countries suffer different impacts of migration including internal and transnational migration [2]. During migration, they carry malaria parasite including drug resistant strains from place to place and may cause growing of drug resistant problem. Moreover, Greater Mekong Subregion countries are approved for malaria elimination at 2030 [3]. Thus, drug resistant and migration problems would be difficult for malaria elimination [4].

According to world malaria report 2016, malaria generated about 212 million cases and malaria mortality was 429,000 in 2015 [5]. In Myanmar, there was 81.1% reduction of reported malaria incidence and 93.5 % reduction in reported annual malaria mortality and 87.2 % reduction in the proportion of malaria hospitalizations in comparison of 2005 to 2014 [6]. Although the total number of malaria cases and deaths had decreased dramatically, malaria remain relatively most prevalent along the border area especially at Myanmar-Thailand borders [2, 7]. Vision of National Malaria Control Program is that *Plasmodium falciparum* elimination at 2025 and *Plasmodium vivax* elimination at 2030 [3, 8].

Dawei district, located in Tanintharyi region, is notable as a trade Hub and a lot of job opportunities are attracting to the migrant workers and some cross border and migrate to Thailand. So, this region has not only internal migration and transnational migration but also many immigrants who have no malaria immunity. These migrant workers have high risk of malaria and then, they may suffer more severe complication [9].

Previous study which was conducted in Thailand-Myanmar border area reported that majority of migrant workers worked at forest related job and residence stayed in the forest had increased risk of malaria infection by a factor of 6.29 (OR = 6.29, 95% CI = 1.56-25.42) [10]. Moreover, Malaria burden is particularly high in hard to reach area of Myanmar-Thailand border and migrant, who attempt to find economic opportunities in this border area because it has a lot of economic development activities including trade market, forestry, industry and road building. Therefore, border areas have been still creating high malaria prevalence and difficult control of malaria problem among migrant population [2]. All of these factors support complex and complicated problem between migrant population and malaria disease.

The main objective of this study was to identify the migration pattern of border migrant people and the factors associated with malaria infection in border areas because these areas have high malaria prevalence, different patterns of migration and few study was available in these border areas especially in Myanmar side. According to these reason, this study was conducted in Myanmar-Thailand border area.

Materials and methods

Study setting

This study was conducted among migrant people who living in Myanmar-Thailand border area of Tanintharyi Region, the southernmost part of Myanmar, especially Dawei, Thayetchaung and Palaw townships where are bordered with Kanchanaburi, Ratchaburi and Phetchaburi Province, Thailand in the East and Andaman sea is located to the West [11]. Forest related worker, refugees camp, ethnic group and mobile migrant workers were living along the border area. The reason of selected these three townships were 1) these areas are bordered with Thailand, 2) mobile migrant workers were passing through these townships and designated to Thailand and 3) malaria prevalence was still high in this region where a better favorable ground provides for malaria infection due to geographic condition [2].

Study design and participants

This study was unmatched case-control study targeting migrant people who lived in Myanmar-Thailand border area during March to May 2018. This study was conducted to know the migration pattern of migrant workers in this area and also determine the possible risks for malaria infection of these people considering on the odd ratio (OR). Sample size of this study was calculated by using the following formula [12] with suggested OR of 1.9 from previous study on migration and malaria was 1.9 [13].

$$n = \left(\frac{r+1}{r}\right)\frac{(\bar{p})(1-\bar{p})\left(Z_{\beta}+Z_{\alpha/2}\right)^2}{(p_1-p_2)^2}$$

Total participant of this study was 320 with 160 cases and 160 controls. The participants were defined as person both male and female, aged 18 years old and above, living currently in the study area and went to volunteer malaria workers or

mobile clinic for malaria screening during March and May 2018. The *Plasmodium* species found in Myanmar are *Plasmodium falciparum* and *Plasmodium vivax* and rapid diagnostic test (SD) detect these *Plasmodium* species. Therefore, participant with positive result from rapid diagnostic test (RDT) for *Plasmodium falciparum, Plasmodium vivax* or mixed infection was recruited to case whereas RDT negative participant was control [14]. However, the malaria infected patient with severe stage of illness and participant who was unwilling to answer the question were excluded. According to vector borne disease control 2015 data, Dawei had 1,607 cases, Thayetchaung had 443 cases and Palaw had 791 cases. Cases and controls were selected as proportional to actual prevalence of malaria to respective townships. Therefore, 89 cases and 89 controls were selected from Dawei, 26 cases and 26 controls were selected from Thayetchaung, and 45 cases and 45 controls were selected from Palaw township.

Data collection and statistically analysis

After confirmation case and control with RDT testing, the participants were provided the information of the study and asked for consent. Data collection was done through face to face interview by using questionnaires asking participant's general characteristics, type of migration, knowledge on malaria, protective behaviors, accessibility and affordability to health services and health seeking behavior. The validity of questionnaires was tested and index of item-objective congruence was 0.94. The reliability of questionnaires was also tested among 30 people at Myeik township. The average value for Kuder–Richardson 20 of knowledge part was 0.78 and for Cronbach's Alpha score of protective behavior part was 0.865. All data analysis was performed by Statistical Package for the Social Science for Windows version 22. Descriptive statistics was mentioned by number and percentage and analytical statistics was conducted bivariate analysis and multiple logistic regression for clear association of independent and dependent variables.

Ethical consideration

Ethical approval to conduct this study was sought from ethical review committee for Research Involving Human Research Subjects, Health Science Group, Chulalongkorn University. Ethical approval no was COA No.079/2018 and approval date was March 26, 2018.

Results

More than half of the respondents conducted interrural migration- migration within one township (border endemic area) and the rest were intermunicipal migration (19.4%) - migration from one township to another township within Tanintharyi Region and interregional migration (27.8%) – migration from one region to another region. Then, about 16.6% of migrant workers crossed the border regularly as pendular migration and some conducted seasonal migration (12.5%) – migration depend on their seasonal job and contract migration (13.4%) – migration regulated by a temporary work program.

Age of the respondents was associated with malaria infection and 18 to 24 years and 25 to 54 years groups were more likely experienced malaria infection about 4.07 times and 2.83 times than 55 to 64 years. Male (crude OR=2.20, p-value=0.001) had higher malaria risk than female. Considering on occupation, forested worker was risk factor for malaria infection and it increased malaria risk about 7.12 times than non-forested worker (crude OR=7.12, p-value<0.001). The main job of migrant workers which related to forest was significant risk factor for malaria infection (crude OR=10.16, p-value<0.001). Residential status was associated with malaria infection and non-local resident increased malaria risk about 1.61 times than local

Table 1. Association between sociodemographic characteristics and malaria infection of migrant workers

Sociodemographic factors	Case	Control	Crude OR	95% CI		*p*-value
	n (%)	n (%)		Lower	Upper	
Age (years)						
55 - 64	9 (26.5%)	25 (73.5%)	1			
18 - 24	44 (59.5%)	30 (40.5%)	4.074	1.670	9.942	0.002*
25 - 54	107 (50.5%)	105 (49.5%)	2.831	1.262	6.351	0.012*
Sex						
Female	59 (39.6%)	90 (60.4%)	1			
Male	101 (59.1%)	70 (40.9%)	2.201	1.406	3.445	0.001*
Occupation						
Non-forested worker	18 (21.4%)	66 (78.6%)	1			
Forested worker	132 (66.0%)	68 (34.0%)	7.118	3.915	12.939	<0.001*
Others	10 (27.8%)	26 (72.2%)	1.410	0.575	3.456	0.452
Forest related job						
Not related	15 (15.5%)	82 (84.5%)	1			
Related	145 (65.1%)	78 (34.9%)	10.162	5.492	18.804	<0.001*
Residential Status						
Local resident	75 (44.4%)	94 (55.6%)	1			
Non-local resident	85 (56.3%)	66 (43.7%)	1.614	1.037	2.512	0.034*
Duration of non-local resident (n=151)						
More 3 years	12 (31.6%)	26 (68.4%)	1			
Under 6 months	41 (73.2%)	15 (26.8%)	5.922	2.398	14.628	<0.001*
Between 6 months and 1 year	18 (66.7%)	9 (33.3%)	4.333	1.512	12.416	0.006*
Between 1 year and 3 years	14 (46.7%)	16 (53.3%)	1.896	0.704	5.108	0.206

Note: *Statistically significant at *p*-value <0.05; total number of participants was 320

Table 2. Association between migration pattern and malaria infection of migrant workers

Migration Pattern	Case	Control	Crude OR	95% CI		*p*-value
	n (%)	n (%)		Lower	Upper	
Interrural migration						
Interrural	75 (44.4%)	94 (55.6%)	1			
Non-interrural	85 (56.3%)	66 (43.7%)	1.614	1.037	2.512	0.034*
Intermunicipal migration						
Intermunicipal	31 (50%)	31 (50%)	1			
Non-intermunicipal	129 (50%)	129 (50%)	1.000	0.574	1.741	1.000
Interregional migration						
Non-interregional	106 (45.9%)	125 (54.1%)	1			
Interregional	54 (60.7%)	35 (39.3%)	1.819	1.106	2.993	0.018*
Pendular migration						
Non-pendular	140 (52.4%)	127 (47.6%)	1			
Pendular	20 (37.7%)	33 (62.3%)	0.550	0.300	1.007	0.053
Seasonal migration						
Non-seasonal	131 (46.8%)	149 (53.2%)	1			
Seasonal	29 (72.5%)	11 (27.5%)	2.999	1.441	6.239	0.003*
Contract migration						
Contract	13 (30.2%)	30 (69.8%)	1			
Non-contract	147 (53.1%)	130 (46.9%)	2.609	1.306	5.214	0.007*

Note: *Statistically significant at *p*-value <0.05; total number of participants was 320

resident. Among non-local residents, under 6 months duration of stay, and between 6 months and 1 year duration of stay were significantly associated with malaria infection (crude OR=5.92, *p*-value<0.001 and crude OR=4.33, *p*-value=0.006, respectively). The results were shown in Table 1.

Regarding to pattern of migration (Table 2), non-interrural migrant workers (crude OR=1.61, *p*-value=0.034) was statistically associated with malaria infection of these migrant workers. Interregional migration also increased malaria risk about 1.82 times than non-interregional migrant workers. Seasonal migration (crude OR=2.99, *p*-value=0.003) and non-contract migration (crude OR=2.60, *p*-value=0.007) were statistically risk factors for malaria infection. But, Intermunicipal migration and pendular migration were not statistically associated with malaria cases and controls. Poor knowledge was increased malaria risk about 3 times than good knowledge. Moreover, the respondents who had moderate and poor protective behavior were also more likely to be infected with malaria comparing with those who performed good protective practice at 5% significance level (crude OR=4.38 and crude OR=7.12, at *p*-value<0.001 respectively) as shown in Table 3.

Multivariate analysis

Sixteen variables which possessed *p*-value<0.2 [15] were included in the multivariate analysis. Younger age groups were still significant associated with malaria infection and risk increased about 6.84 (18 to 24 years) and 6.07 times (25 to 54 years) than older age group. Forest related job was still significantly risk factors (adjusted OR=5.28, *p*-value= 0.020) for malaria infection.

Non-contract migrant worker was statistically risk factor for malaria infection compared with contract migrant worker. Poor knowledge (adjusted OR=3.98, *p*-value=0.005), moderate protective behavior (adjusted OR=5.70, *p*-value=0.001) and poor protective behavior (adjusted OR=8.85, *p*-value<0.001) were statistically associated with malaria infection. Moreover, respondents who had difficulty in access to malaria health services were still risk factor for malaria infection. Respondents who sought malaria treatment after 24 hours were increase malaria risk about 3.03 times than respondent who sought malaria treatment within 24 hours at 5% significance level as shown in Table 4.

Table 3. Association of knowledge and protective behavior with malaria infection of migrant workers

Variables	Case	Control	Crude OR	95% CI		*p*-value
	n (%)	n (%)		Lower	Upper	
Knowledge						
Good knowledge	22 (37.3%)	37 (62.7%)	1			
Moderate knowledge	61 (43.3%)	80 (56.7%)	1.282	0.687	2.394	0.435
Poor knowledge	77 (64.2%)	43 (35.8%)	3.012	1.578	5.747	0.001*
Protective behavior						
Good protective behavior	8 (19.0%)	34 (81.0%)	1			
Moderate protective behavior	95 (50.8%)	92 (49.2%)	4.389	1.929	9.982	<0.001*
Poor protective behavior	57 (62.6%)	34 (37.4%)	7.125	2.957	17.169	<0.001*

Note: *Statistically significant at *p*-value <0.05; total number of participants was 320

Table 4. Effect of sociodemographic, migration, knowledge, protective behavior and treatment seeking behavior on malaria infection in multivariate analysis

Variables	Adjusted OR	95% CI		*p*-value
		Lower	Upper	
Age (years)				
55 - 64	1			
18 - 24	6.848	1.730	27.109	0.006*
25 - 54	6.071	1.758	20.971	0.004*

(continued)

Table 4. (continued)

Variables	Adjusted OR	95% CI		*p*-value
		Lower	Upper	
Sex				
Female	1			
Male	1.175	0.619	2.232	0.621
Occupation				
Non-forested worker	1			
Forested worker	2.483	0.578	10.660	0.221
Others[1]	2.019	0.528	7.716	0.304
Forest related				
Not related	1			
Related	5.287	1.296	21.570	0.020*
Interrural migration				
Interrural migration	1			
Non-interrural	1.280	0.533	3.073	0.581
Interregional migration				
Non-interregional	1			
Interregional	1.968	0.710	5.456	0.193
Pendular migration				
Non-Pendular	1			
Pendular	0.615	0.214	1.770	0.368
Seasonal migration				
Non-seasonal	1			
Seasonal	0.833	0.284	2.444	0.739
Contract migration				
Contract	1			
Non-contract	106.218	9.685	1164.938	<0.001*
Knowledge				
Good knowledge	1			
Moderate knowledge	1.542	0.645	3.690	0.330
Poor knowledge	3.982	1.516	10.456	0.005*
Protective behavior				
Good protective behavior	1			
Moderate protective behavior	5.702	2.061	15.779	0.001*
Poor protective behavior	8.858	2.822	27.805	<0.001*
Duration of travel to health facility (minutes)				
≤ 30	1			
≥ 30	2.192	0.899	5.342	0.084
Ability to access malaria health services				
Easy access	1			
Difficult access	34.286	4.379	268.480	0.001*
Financial difficulties				
No financial difficulties	1			
Having financial difficulties	0.948	0.301	2.993	0.928
History of malaria infection				
Never get infection	1			
Ever get infection	1.372	0.679	2.774	0.379
Seeking malaria treatment				
Within 24 hours	1			
After 24 hours	3.034	1.411	6.526	0.005*

Note: *Statistically significant at *p*-value <0.05; total number of participants was 320

Discussion

This study was conducted to identify migration pattern and specify associated factors for malaria infection. Majority of respondents were male with middle age, forested workers and local residents. Younger age group had statistically higher odd

ratio than middle age group compared with older age group (55 to 64 years) at 5% significance level. This finding was agreed with previous study in which younger age had high risk of malaria infection than older age [16]. Male increased malaria risk 2.2 time than female at 95% confidence interval. This fact was matched with WHO malaria report that mentioned male had higher occupation risk than female [17]. Then, forested workers increased malaria risk about 7.11 times than non-forested workers at 5% significance level because they had more chance to expose to *Anopheles* mosquito in the forest. This event was coincided with other study in which forested workers had high malaria infection than others occupation [9, 18]. However, other occupations were not statistically associated with malaria infection at 95% confidence interval. The job nature of migrant worker was important factor for malaria infection. Respondents with forest related job had suffered malaria infection about 10 times than migrant worker whose job was not related to forest at 5% significance level due to more exposure to *Anopheles*. This event agreed with other study in which forest related worker had high odd ratio than non- forest related workers [19].

Non-local residents were risk factor and they increased malaria infected risk about 1.6 times than local resident because it could be assumed that they had no malaria immunity whereas local residents had developed malaria immunity. Among non-local resident, their duration of stay after arrival this border area, under 6 months increased malaria infection risk about 5.9 times and between 6 months and 1 years had increased malaria infection risk about 4.33 times than more than 3 years migration at 95% confidence interval. It could be assumed that they already developed malaria immunity if they live in the endemic area for longer time with frequently exposed to malaria parasites but under 1 year duration, the immunity had not well-developed. This fact supported with other study done in Myanmar-Thailand border area in which recent migrant worker had higher malaria infected risk than local resident or long duration of migration in endemic area [7]. Some study reported that immunity developed after heavy, frequency, uninterrupted exposure to *Plasmodium* species [20].

Non-interrural migrant workers were likely to occur malaria infection (1.6 times increased) than interrural migration workers (p-value= 0.034) due to no immunity in non-interrural migrant workers. This phenomena was supported with other study in which they mentioned that people living in endemic area acquired immunity due to frequent exposure [21].

There was no association between intermunicipal migration and malaria infection because all of these migrant workers were living in Tanintharyi region and it is also malaria endemic area. Therefore, it can be assumed that these migrant workers had already developed malaria immunity. Interregional migration was about one third of total migration and mostly came from Ayyawaddy and Bago regions where malaria is not endemic. Interregional migration was increased malaria infection risk about 1.8 times than non-interregional migration due to no immunity in these migrant workers. The phenomena was supported with previous study in which they mentioned about the consequences of malaria immunity [20]. Pendular migration was few number and was not associated with malaria infection because these migrant workers easily accessed to malaria health services and they stayed in the way of border area due to their working nature. In contrary, seasonal migration had experienced on malaria infection about 2.99 times than non-seasonal migrant worker because it was seasonal disease [22].

Non-contract migrant worker was statistically risk factor for malaria infection and they increased more malaria infected risk about 2.61 times compared with contract migrant workers at 95% confidence interval. The reason of relatively high

malaria infection risk in non-contract migrant worker was that most of the contract migrant workers had their own health services and protective measures provided by their company or contractor whereas non-contract migrant worker who had no health services. Therefore, contract migration was less likely to be infected. Poor knowledge increased about 3 times of malaria risk than good knowledge (p-value=0.001). This fact agreed with other study in which poor knowledge had high odd ratio than good knowledge which was conducted in Myanmar-Thailand border area [23]. Only 5% of total cases had good protective behavior whereas about 80% of controls had good and moderate protective behavior. Poor and moderate protective behaviors rose more malaria infection risk about 7.1 times and 4.3 times than good protective behavior as reference group at 5% significance level.

In multivariate analysis, among 16 independent variables (p-value<0.2), only 7 independents variables were still significant at 95% confidence interval after analysis of multiple logistic regression. These significance independent variables were age, forested related job, contract migration, knowledge, protective behavior, easy access to malaria health services and seeking malaria treatment after 24 hours.

Conclusion

According to this study, many factors predicted to malaria infection and these factors suggested that regular health services should be provided to high risk migrant workers and development of migration information network for quick intervention process. The limitation of this study was that migrant population was huge community, difficult to access all detail information and recall bias due to study type. To get more valid data, future study should be conducted expanding to all migrant workers with one-year duration for seasonal trend of infection.

Acknowledgement

This research was supported with "Thesis Grant of Graduate School, Chulalongkorn University". I would like to express sincere gratitude to all participants of my study and all field staffs of University Research Co., LLC for all assistance during data collection. I would like to say thank again to all people who involved in my study directly or indirectly.

References

1. Roll Back Malaria Partnership. Action and investment to defeat malaria 2016-2030: for a malaria-free world. Geneva: World Health Organization; 2015.
2. Jitthai N. Migration and malaria. Southeast Asian J Trop Med Public Health. 2013; 44(Suppl 1): 166-200; discussion 306-7.
3. World Health Organization [WHO], Regional Office for the Western Pacific. Strategy for malaria elimination in the Greater Mekong Subregion: 2015-2030. Manila: WHO Regional Office for the Western Pacific; 2015.
4. World Health Organization [WHO]. Malaria in the greater mekong subregion. WHO; 2010.
5. World Health Organization [WHO]. World malaria report 2016. Geneva: WHO; 2016.
6. Mu TT, Sein AA, Kyi TT, Min M, Aung NM, Anstey NM, et al. Malaria incidence in Myanmar 2005-2014: steady but fragile progress towards elimination. Malar J. 2016 Oct; 15(1): 503. doi: 10.1186/s12936-016-1567-0
7. Sriwichai P, Karl S, Samung Y, Kiattibutr K, Sirichaisinthop J, Mueller I, et al. Imported Plasmodium falciparum and locally transmitted Plasmodium vivax: cross-border malaria transmission scenario in northwestern Thailand. Malar J. 2017 Jun; 16(1): 258. doi: 10.1186/s12936-017-1900-2
8. Thi A. Current situation of Malaria in Myanmar and updated NMTG. Nay Pyi Taw: National Malaria Control Program; 2017. (unpublished work)

9. Tipmontree R, Fungladda W, Kaewkungwal J, Tempongko MA, Schelp FP. Migrants and malaria risk factors: a study of the Thai-Myanmar border. Southeast Asian J Trop Med Public Health. 2009 Nov; 40(6): 1148-57.

10. Chaveepojnkamjorn W, Pichainarong N. Malaria infection among the migrant population along the Thai-Myanmar border area. Southeast Asian J Trop Med Public Health. 2004 Mar; 35(1): 48-52.

11. United Nations Development Programme [UNDP]. The state of local governance: Trend in Tanintharyi. Yangon, Myanmar: UNDP; 2014.

12. Kelsey JL, Whittemore AS, Evans AS, Thompson WD. Methods in Observational epidemiology. 2nd ed. New York: Oxford University Press; 1996.

13. Lynch CA, Bruce J, Bhasin A, Roper C, Cox J, Abeku TA. Association between recent internal travel and malaria in Ugandan highland and highland fringe areas. Tropical Medicine & International Health. 2015 Jun; 20(6): 773-80. doi: 10.1111/tmi.12480

14. World Health Organization [WHO]. Malaria Diagnosis test performance. WHO; 2015.

15. Hosmer DW, Jr., Lemeshow S, Sturdivant RX. Applied logistic regression. 3rd ed. New Jersey: John Wiley & Sons; 2013.

16. Chaveepojnkamjorn W, Pichainarong N. Behavioral factors and malaria infection among the migrant population, Chiang Rai province. J Med Assoc Thai. 2005 Sep; 88(9): 1293-301.

17. World Health Organization [WHO]. Gender, health and malaria. WHO; 2007.

18. Bhumiratana A, Intarapuk A, Sorosjinda-Nunthawarasilp P, Maneekan P, Koyadun S. Border malaria associated with multidrug resistance on Thailand-Myanmar and Thailand-Cambodia borders: transmission dynamic, vulnerability, and surveillance. Biomed Res Int. 2013; 2013: 363417. doi: 10.1155/2013/363417

19. Erhart A, Ngo DT, Phan VK, Ta TT, Van Overmeir C, Speybroeck N, et al. Epidemiology of forest malaria in central Vietnam: a large scale cross-sectional survey. Malar J. 2005 Dec; 4(1): 58. doi: 10.1186/1475-2875-4-58

20. Doolan DL, Dobaño C, Baird JK. Acquired immunity to malaria. Clin Microbiol Rev. 2009; 22(1): 13-36. doi: 10.1128/CMR.00025-08

21. Chiyaka C, Garira W, Dube S. Transmission model of endemic human malaria in a partially immune population. Mathematical and Computer Modelling. 2007 Sep; 46(5-6): 806-22. doi: 10.1016/j.mcm.2006.12.010

22. Hu Y, Zhou G, Ruan Y, Lee MC, Xu X, Deng S, et al. Seasonal dynamics and microgeographical spatial heterogeneity of malaria along the China-Myanmar border. Acta Trop. 2016 May; 157: 12-9. doi: 10.1016/j.actatropica.2016.01.022

23. Htike YM. Environmental factors for malaria infection in Thanintharyi region, Myanmar : a case-control study. Bangkok: Chulalongkorn University; 2015.

Corresponding author

Tepanata Pumpaibool can be contacted at: Tepanata.P@Chula.ac.th