Malaria Journal

RESEARCH

Open Access

Knowledge, attitude and practice levels regarding malaria among the Semai sub-ethnic indigenous Orang Asli communities in Pahang, Peninsular Malaysia: a stepping stone towards the prevention of human malaria re-establishment

Luqman Samsudin[1*], Muhammad Farhan Mohd Jaafar[1], Mohamad Khairul Anam Kamarulzaman[1], Noor Natasha Mohd Nor[1], Shafizah Ahmad Shafei[1], Nurul Ainaa Mohamad Shukor[1], Mohammed Rohaimie Abdul Rahman[1], Kumuthamalar Sangaran[2,3], Wan Rosmawati Wan Ismail[4], Jenn Zhueng Tam[5] and Zulkarnain Md Idris[2*]

Abstract

Background In Malaysia, despite a decline in cases, malaria remains a major public health concern, especially among the vulnerable indigenous people (i.e. Orang Asli) in remote areas. Effective preventive and control measures require an evidence-based understanding of their knowledge, attitudes, and practices (KAP) regarding malaria. This study aimed to evaluate the KAP regarding malaria in an indigenous settlement in Peninsular Malaysia.

Methods A household-based cross-sectional study was conducted in March 2024 in six Semai sub-ethnic indigenous villages in Pos Lenjang, Kuala Lipis, Pahang. A structured questionnaire was administered to randomly selected individuals (≥ 12 years old) to collect data on sociodemographic characteristics and KAP. Data were analysed using descriptive statistics and predictors of KAP were determined using logistic regression. A p-value less than 0.05 was considered statistically significant.

Results A total of 267 individuals from 160 households were interviewed. Nearly half had good knowledge (49.4%) and positive attitudes (54.3%) towards malaria, with high practice scores for prevention and control (83.1%). Multivariate logistic regression analysis showed higher odds of good knowledge in those aged 40–59 years (adjusted odd ratio [aOR] = 6.90, p = 0.034), with primary (aOR = 2.67, p = 0.015) or secondary education (aOR = 2.75, p = 0.019), and with previous malaria history (aOR = 5.14, p < 0.001). Higher odds of a good attitude were found in those with secondary education (aOR = 4.05, p < 0.001) and previous malaria history (aOR = 2.74, p = 0.017). Lower odds

*Correspondence:
Luqman Samsudin
luqman.samsudin@moh.gov.my
Zulkarnain Md Idris
zulkarnain.mdidris@ukm.edu.my
Full list of author information is available at the end of the article

were observed for the unemployed (aOR = 0.25, p = 0.018) and those collecting forest products (aOR = 0.25, p = 0.049) for attitude and practice, respectively.

Discussion The overall practice level on malaria prevention was high among the Semai Orang Asli in Pahang. However, to ensure sustainability, the low levels of knowledge and attitude regarding malaria must be strengthened through increased health education and continuous community engagement.

Keywords Malaria, KAP, Indigenous people, Orang Asli, Malaysia

Background

Malaria is a significant global public health challenge, particularly in tropical and subtropical regions. The disease is caused by five species of *Plasmodium* parasites known to infect humans: *Plasmodium falciparum*, *Plasmodium vivax*, *Plasmodium malariae*, *Plasmodium ovale* and *Plasmodium knowlesi* [1]. In Malaysia, despite reported zero indigenous human malaria cases since 2018, due to ecological changes, particularly deforestation, there has been a rise in the exposure of humans to vectors of zoonotic *Plasmodium* and non-human primates, including long-tailed macaques (*Macaca fascicularis*) and pig-tailed macaques (*Macaca nemestrina*) [2]. This has led to a new trend in the transmission of *P. knowlesi*, a malaria parasite from simians, with cases escalating from 376 cases in 2008 to 3575 cases with 13 deaths in 2021 [3].

In Peninsular Malaysia, one of the most vulnerable communities to malaria is the indigenous minority peoples of Orang Asli. They are categorized into three main groups based on linguistic and cultural differences and are further divided into six different sub-ethnics: Negrito (i.e. Kensiu, Kintak, Jahai, Lanoh, Mendriq, Batek), Senoi (i.e. Temiar, Semai, Jah Hut, Semoq Beri, Che Wong, Mah Meri), and Proto-Malay (i.e. Temuan, Semelai, Jakun, Orang Kanaq, Orang Kuala, Orang Seletar) [4]. The Senoi population represents the largest group of the Orang Asli in Malaysia (54.9%), followed by the Proto Malay (42.3%) and Negrito (2.8%) [5]. Predominantly residing in remote and forested areas throughout Peninsular Malaysia, they are susceptible and vulnerable to malaria [2, 6]. A recent epidemiological study revealed that the prevalence of asymptomatic and submicroscopic malaria among the Temiar sub-ethnic group of Senoi in remote Peninsular Malaysia was 0.4%, with a significantly high proportion among the group of 19 to 40 years old [7]. Another recent study within the same indigenous Orang Asli communities also revealed heterogeneity in serological indices with a higher level of *P. falciparum* transmission based on seroconversion rate, than *P. vivax* in the study area [8]. Essentially, the previous studies have provided critical information on the hidden burden, age-specific vulnerability, transmission dynamics, and health inequities of malaria among the Orang Asli communities, which are essential for designing and implementing effective malaria control and elimination strategies.

One of the Senoi indigenous Orang Asli settlements (i.e. Semai sub-ethnic) of interest is Pos Lenjang in Kuala Lipis, Pahang, home to the Semai sub-ethnic group. In 2019, there was an outbreak of malaria caused by *P. vivax* in Pos Lenjang, affecting three of the thirteen villages, namely Kg. Pagar, Kg. Sop, and Kg. Serdang [9]. *Anopheles maculatus* is the most common malaria vector in the area [10, 11]. The outbreak began with imported cases through foreign workers in the area, subsequently spreading to the local communities, resulting in an attack rate of 4.1% (33 cases of *P. vivax* mono-infection). Once the outbreak occurred, the locality was gazetted as an Active Focus and kept under malaria surveillance for the subsequent three years. In 2020, the surveillance system managed to identify seven additional introduced infections of *P. vivax* in different villages of Pos Lenjang, specifically Kg. Tungau and Kg. Kenderong. Between 2021 and 2023, there were a total of eleven relapsed *P. vivax* malaria cases from Kg. Lenjang (5 cases), Kg. Serdang (3 cases), Kg. Tungau (2 cases), and Kg. Pagar (1 case). These patients were all treated in 2019 but relapsed again over the years. In Malaysia, all malaria blood samples have to be further tested using molecular testing, and the results showed that the *P. vivax* parasites in all eleven cases were similar to the *P. vivax* parasites in 2019 (unpublished data, Vector Borne Disease Sector, Ministry of Health, Malaysia). The experience in Kuala Lipis district, Pahang, significantly demonstrates the importance of molecular testing capacities when a country reaches the end of their malaria elimination phase.

Understanding knowledge, attitudes, and practices (KAP) towards malaria is paramount for effective malaria control and elimination strategies. Knowledge about malaria transmission, symptoms, and preventive measures is fundamental for individuals to protect themselves and seek timely treatment. Attitudes towards malaria can significantly influence health-seeking behaviour, adherence to preventive measures, and acceptance of interventions such as insecticide-treated bed nets and indoor residual spraying. Practices related to malaria, such as the use of protective measures, and treatment-seeking behaviour, directly impact malaria transmission and control

efforts. Combining these three components provides a holistic understanding of how communities perceive, prevent, and manage malaria, which is crucial for designing targeted and effective interventions, especially in indigenous populations. For instance, a study in the Lihir Islands of Papua New Guinea among the indigenous people of Melanesian descent found that low utilization of bed nets despite universal coverage of insecticide-treated nets (ITNs) attributed to the low KAP level on malaria prevention in the community [12]. Similarly, a study in Chhattisgarh state in India among the aboriginal Gond tribe emphasized the need for tailored health education campaigns to improve KAP towards malaria among marginalized communities [13]. These studies collectively highlight the significance of understanding KAP towards malaria for designing effective interventions and achieving malaria control and elimination targets.

In Malaysia, numerous epidemiological studies on malaria infection have been conducted throughout the country. However, only two studies have specifically assessed the KAP towards malaria among indigenous Orang Asli communities in the past decades [6, 14]. Moreover, these two studies focused either on different sub-ethnic groups of Orang Asli or zoonotic malaria infection. Given the high vulnerability of malaria among the hard-to-reach Orang Asli communities in Malaysia, understanding their KAP towards malaria is crucial. In addition, it remains unclear whether the different levels of KAP towards malaria, the remote settlements, and the different tribes of Orang Asli could be potential factors influencing ongoing malaria transmission in the community. Therefore, this study was undertaken to investigate the KAP and the associated factors regarding malaria among community members of the Senoi indigenous Orang Asli, who reside in the remote interior part of Peninsular Malaysia.

Methods

Ethics consideration

The study protocol was approved by the Medical Research Ethics Committee of the National Institute of Health Malaysia (Reference no. NMRR ID-24-00476-KIE) and the Department of Orang Asli Development, locally known as the Jabatan Kemajuan Orang Asli (JAKOA), Ministry of Rural and Regional Development Malaysia [Reference no. JAKOA.PP.R.004 JLD 5(48)].

Study area and population

This study was conducted in Pos Lenjang (N4° 15.413′ E101° 32.843), a cluster of 13 small indigenous villages of the Semai sub-ethnic group of Senoi indigenous Orang Asli, located in Ulu Jelai sub-district, Kuala Lipis district of Pahang state, Peninsular Malaysia (Fig. 1). The estimated population of Pos Lenjang is 2534 people, with 490 houses (unpublished data, Lipis District Health Office, Ministry of Health, Malaysia). Situated about 90 km from Kuala Lipis town and 240 km east of Kuala Lumpur, this settlement is equipped with one government health facility (a rural clinic) and a primary school. Farming and the collection and sale of forest products are the major economic activities for the community. Farming is mostly subsistence-based, with major crops including rubber and palm oil, as well as small-scale animal husbandry. The climate is tropical monsoon, with average annual rainfall between 86 and 321 mm and temperatures ranging from 24.6 to 26.8 °C. All villages share a similar environment, being situated near forest fringes and adjacent to river basins [11].

The villages in Pos Lenjang are carved out of secondary forest situated on hilly terrain, with most being riverine. Most of these villages are in remote areas, accessible only by four-wheel drive vehicles, while others can only be reached on foot. The Pos Lenjang population continues to live a semi-nomadic lifestyle. Villages in Pos Lenjang are not static, as houses and sometimes whole villages may be relocated to remain within convenient walking distance of garden crops, which are periodically moved to different places to reflect agricultural practices within traditional land tenure areas.

Study design and data collection

The community-based cross-sectional survey was conducted in six out of thirteen villages in March 2024. These villages, namely Kg. Tungau, Kg. Lenjang, Kg. Pagar, Kg. Serdang, Kg. Sop and Kg. Kenderong, were purposely selected because each had reported *P. vivax* cases since the malaria outbreak in 2019. A simple random sampling technique was used to select the household units included in this study. The study protocol and consent process were explained to the participants, and their voluntary consent was documented. Written informed consent was obtained from each adult participant at study registration. For the illiterate participant, written informed consent was obtained in the presence of an independent literate witness. For children and adolescents below 18 years old, written informed consent were obtained from parents or legal guardians. All residents aged 12 years and above in the selected household units were enrolled as study participants after consenting. Prior to data collection, a meeting was held between the researchers (LS, MFMJ and MKAK) and the head of villages (i.e. Tok Batin) to explain the study protocol, ensuring good participation among the community.

A validated Malay language version of a questionnaire by Munajat et al. was used to assess knowledge about malaria and their practice level regarding malaria

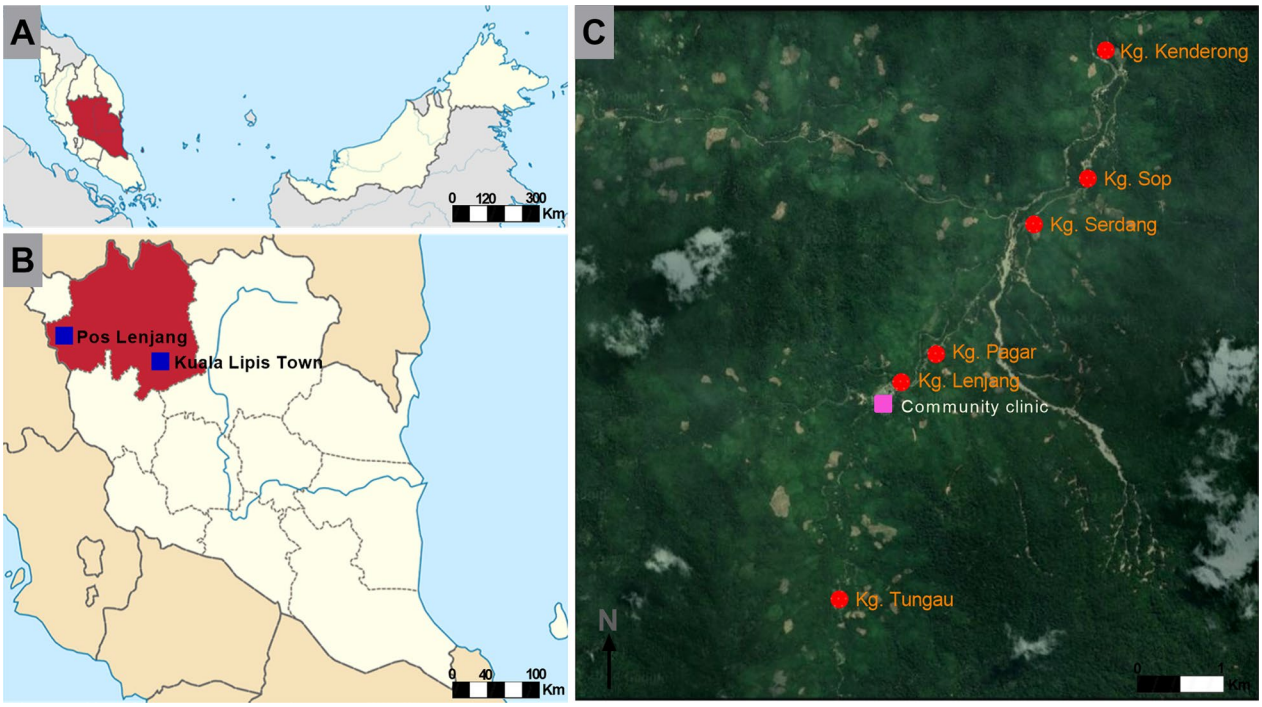

Fig. 1 Map of the study area. **A** Map of Malaysia showing the location of Pahang state (red) in Peninsular Malaysia. **B** Map of Kuala Lipis district (red) showing the location of Pos Lenjang (blue square) and Kuala Lipis town (blue square). **C** The location of a community clinic (pink square) and the six study villages (red circle) in Pos Lenjang namely, Kg. Tungau, Kg. Lenjang, Kg. Pagar, Kg. Serdang, Kg. Sop and Kg. Kenderong

prevention [6]. For attitude levels on malaria, a Likert scale from Tairou et al. was adopted [15], and translated into Malay. The translated questionnaire was pre-tested in another setting, the Semai tribe indigenous village in Kuala Koyan, to check for accuracy. Based on the pilot study, the questionnaire was modified. The reliability test was conducted, and the calculated Cronbach's alpha was 0.8. Before conducting the interview, the lead researcher (LS) held a training session to brief the survey team members on each question in the questionnaire and the proper way to conduct the interviews. Eight local staffs from the Lipis District Health Office and a surveyor from the Universiti Kebangsaan Malaysia visited the selected household and conducted face-to-face interviews using Malay or the local dialect.

Sample size calculation

The number of households included in the survey was determined by using the Krejcie and Morgan Table [16]. Given that the total number of households in the selected villages was 264, with a 10% non-response rate, the final sample size is 160 households.

Data analysis

The responses collected were tabulated into a spreadsheet in Microsoft Excel (Microsoft, USA). The cleaned data was analyzed using SPSS statistical software version 27 (IBM, USA). Categorical variables were expressed as frequency and percentage, while continuous variable was presented as median with interquartile range (IQR). Chi-square or Fisher's exact test was used to test the difference between respondent characteristics. The effect of predictive variables (age group, sex, education level, monthly income in Malaysian Ringgit (MYR), occupation, previous history of malaria infection) on good knowledge, good attitudes, and good practices was tested by using logistic regression. The level of significance was set at $p < 0.05$.

To assess respondent's knowledge of malaria, three items were evaluated: correct identification of the mode of transmission, identification of the signs and symptoms of malaria, and knowledge of malaria prevention [15]. A knowledge score was calculated by summing the respondent's score across the three domains. Only respondents who described mosquito bites as the mode of transmission were given a score of one. For knowledge of malaria symptoms, those who correctly identified the symptoms of malaria (fever, headache, body ache, rigours or chills, nausea, vomiting, diarrhoea) were given one mark for each correct answer. For knowledge of malaria prevention, respondents who identified bed nets as a means to

prevent malaria were given a score of 1, and those who answered any of the following prevention measures: indoor residual spray, draining stagnant water, wearing protective clothing, using mosquito coils, taking medication, and avoiding mosquito biting times, were given a score 0.5 for each answer. The median of the total score was taken as a cutoff to categorize knowledge of malaria into two levels: poor (equal to or below the median) and good (above the median) levels of knowledge of malaria [15].

For attitudes towards malaria, six items related to the population at risk, treatment, and prevention of malaria were used. The scoring was based on a Likert scale, where strongly agree (score 5), agree (score 4), neutral (score 3), disagree (score 2), and strongly disagree (score 1). An attitude score was generated by adding up each respondent's score across the six items. Those who scored above the median of the total score were classified as having positive attitudes, while others were classified as having negative attitudes. Meanwhile, the practice of the respondents regarding malaria prevention was defined based on the ownership and usage of ITNs. Respondents who owned ITNs and used them three or more times per week were considered to have good prevention practices, whereas those who did not possess ITNs or those who possessed them but used them less than three nights per week were considered to have poor prevention practices. To assess the overall level of each KAP category, a modified Bloom's cutoff was adapted, using a score above 60% of correct answers to indicate a good level and a score below 60% to indicate a poor level [17].

Results

Socio-demographic characteristics of respondents

A total of 267 respondents from 160 households participated in this study. Table 1 shows the socio-demographic characteristics of the study participants. More than half of the participants were female (52.8%). The median age of the respondents was 33 years (IQR: 23–45), with most participants aged between 19 and 39 years (47.6%). Respondents with a secondary level of education constituted 41.6% of the study. The majority of the participants were self-employed, practising agriculture (40.1%) as their main source of income, and 94.4% had a monthly household income of less than MYR500, or approximately USD118. Additionally, a small percentage of respondents reported a history of malaria infection (13.9%). Of the 160 surveyed households, most houses were constructed with bamboo materials, such as walls (88.8%) and floors (88.4%), with corrugated zinc used for the roof (94.8%) (Fig. 2).

Knowledge about malaria causes, symptoms, and prevention

Out of the 267 respondents surveyed, less than half knew the mode of transmission of malaria (46.1%), and of those, 82.1% identified mosquito bites as the mode of transmission (Table 2). Meanwhile, other factors reported by the respondents included stagnant water (9.8%), dirty surroundings (5.7%), contact with malaria patients (1.6%), and poor nutrition (0.8%). A slight majority of respondents knew about the symptoms of malaria (51.3%), and the most commonly reported symptoms were rigour (35.4%) and fever (30.6%). Similarly, a slight majority of respondents knew how to prevent malaria (52.4%), with sleeping under a bed net (58.6%) being the most reported preventive method. Other common prevention methods reported included draining stagnant water (21.8%) and applying IRS (9.2%). Furthermore, the majority of respondents indicated knowing how to manage illness (90.6%), and most respondents preferred seeking treatment immediately at a clinic (93.9%), followed by a traditional healer (4.5%). Seeking treatment by purchasing medication from the local shop was the least preferred option (0.4%). Overall, only 49.4% of the respondents had a good level of knowledge regarding malaria.

Attitude towards malaria

Table 3 shows respondents' attitudes towards malaria among indigenous Orang Asli communities in Pos Lenjang. Overall, 45.7% of respondents believed that everybody could be infected by malaria. The majority believed malaria was a deadly disease (88.8%, n = 237) but that it could be prevented (77.9%, n = 208). Furthermore, most respondents also believed that malaria could be cured with medical treatment (85.8%, n = 229), that malaria testing was necessary prior to the commencement of anti-malaria treatment (82.4%, n = 220), and that it was essential to complete malaria treatment when prescribed (91.1%, n = 243). Based on attitude score calculations, 54.3% of the respondents had a good level of attitude towards malaria.

Practice of malaria prevention

In terms of malaria control measures, the overall level of ITN utilization and compliance for nightly usage were high in the community at 84.3% and 94.7%, respectively (Table 1). A small percentage (3.7%) of respondents reported not using any bed net. Among the reasons given were the absence of an ITN (77.8%), forgetfulness (11.1%), and feeling hot and trapped inside (11.1%). Furthermore, indoor residual spraying (IRS) by the health authority covered 95.1% of all

Table 1 Socio-demographic data of respondents, households and malaria control measures according to villages in Pos Lenjang, Kuala Lipis, Pahang in 2024

Characteristics	Overall	Kg. Tungau	Kg. Lenjang	Kg. Pagar	Kg. Serdang	Kg. Sop	Kg. Kenderong
Total number of surveyed households, N	160	20	28	36	13	31	32
Total number of respondents, n	267	36	53	53	35	48	42
Gender, n (%)							
Male	126 (47.2)	14 (38.9)	23 (43.4)	27 (50.9)	18 (51.4)	23 (47.9)	21 (50)
Female	141 (52.8)	22 (68.1)	30 (56.6)	26 (49.1)	17 (48.6)	25 (52.1)	21 (50)
Age, median (IQR), years	33 (23–45)	29 (19–44)	31 (21–43)	39 (28–47)	30 (17–44)	34 (23–43)	38 (24–46)
Age group, n (%), years							
12–18	35 (13.1)	9 (25)	6 (11.3)	4 (7.5)	9 (25.7)	4 (8.3)	3 (7.1)
19–39	127 (47.6)	15 (41.7)	27 (50.9)	23 (43.4)	14 (40)	28 (58.3)	20 (47.6)
40–59	90 (33.7)	11 (30.6)	15 (28.3)	21 (39.6)	10 (28.6)	14 (29.2)	19 (45.2)
≥ 60	15 (5.6)	1 (2.8)	5 (9.4)	5 (9.5)	2 (5.7)	2 (4.2)	0 (0)
Educational level, n (%)							
No formal education	68 (25.5)	10 (27.8)	10 (18.9)	15 (28.3)	6 (17.1)	8 (16.7)	19 (45.3)
Primary	83 (31.1)	13 (36.1)	19 (35.8)	18 (34.0)	13 (37.1)	11 (22.9)	9 (21.4)
Secondary	111 (41.6)	12 (33.3)	24 (45.3)	17 (32.1)	16 (45.8)	28 (58.3)	14 (33.3)
Tertiary	5 (1.8)	1 (2.8)	0 (0)	3 (5.6)	0 (0)	1 (2.1)	0 (0)
Occupation, n (%)							
Housewife	89 (33.3)	14 (38.9)	19 (35.8)	20 (37.7)	8 (22.9)	14 (29.2)	14 (33.3)
Student	25 (9.4)	6 (16.7)	2 (3.8)	3 (5.7)	9 (25.7)	2 (4.2)	3 (7.1)
Agriculture	107 (40.1)	10 (7.8)	24 (45.3)	23 (43.4)	10 (28.6)	27 (56.3)	13 (31)
Forestry	14 (5.2)	0 (0)	1 (1.9)	3 (5.7)	2 (5.7)	1 (2.1)	7 (16.7)
Formal employment	12 (4.5)	0 (0)	5 (9.4)	1 (1.9)	4 (11.4)	1 (2.1)	1 (2.4)
Unemployed	20 (7.5)	6 (16.7)	2 (3.8)	3 (5.7)	2 (5.7)	3 (6.1)	4 (9.5)
Monthly income (MYR), n (%)							
≤ 500	252 (94.4)	36 (100)	47 (88.7)	51 (96.2)	31 (88.6)	46 (95.8)	41 (97.6)
> 500	15 (5.6)	0 (0)	6 (11.3)	2 (3.8)	4 (11.4)	2 (4.2)	1 (2.4)
Previous malaria infection, n (%)							
Yes	37 (13.9)	3 (8.3)	12 (22.6)	6 (11.3)	4 (11.4)	9 (24.1)	3 (7.1)
No	230 (86.1)	33 (91.7)	41 (77.4)	47 (88.7)	31 (88.6)	39 (75.9)	39 (92.9)
Bed net ownership, n (%)							
ITN	225 (84.3)	32 (88.9)	45 (84.9)	45 (84.9)	33 (94.2)	41 (85.4)	29 (69)
Non-ITN	32 (12)	1 (2.8)	8 (15.1)	6 (11.3)	1 (2.9)	4 (8.3)	12 (28.6)
Not using bed net	10 (3.7)	3 (8.3)	0 (0)	2 (3.8)	1 (2.9)	3 (6.3)	1 (2.4)
ITN utilization, n (%)							
Every nights	213 (94.7)	28 (87.5)	41 (91.1)	45 (100)	32 (9)	38 (92.7)	29 (100)
3–6 nights	9 (4)	4 (12.5)	3 (6.7)	0 (0)	1 (3)	1 (2.4)	0 (0)
< 3 nights	3 (1.3)	0 (0)	1 (2.2)	0 (0)	0 (0)	2 (4.9)	0 (0)
IRS within the last 12 months, n (%)							
Yes	254 (95.1)	36 (100)	53 (100)	52 (98.1)	34 (97.1)	37 (77.1)	42 (100)
No	13 (4.9)	0 (0)	0 (0)	1 (1.9)	1 (2.9)	11 (22.9)	0 (0)

MYR Malaysian Ringgit, *IQR* interquartile range, *IRS* indoor residual spraying, *ITN* insecticide-treated net

surveyed households. Overall, 83.1% of the respondents had a good level of prevention practice against malaria (Table 2).

Factors associated with knowledge, attitude and practice on malaria

The univariate logistic regression analysis of factors

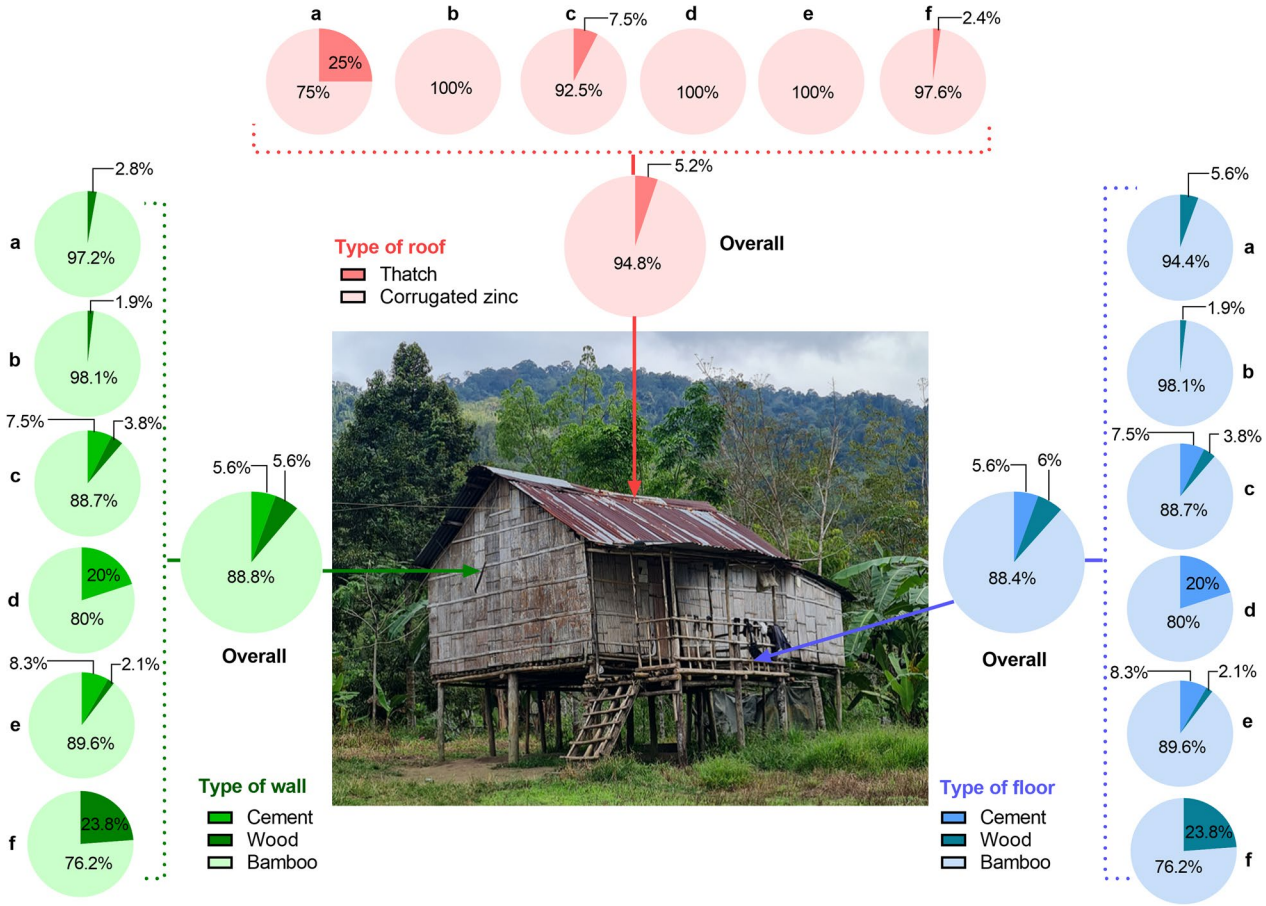

Fig. 2 A typical housing structure in the indigenous Orang Asli settlements of Pos Lenjang, Kuala Lipis, Pahang. **a** Kg. Tungau, **b** Kg. Lenjang, **c** Kg. Pagar, **d** Kg. Serdang, **e** Kg. Sop and **f** Kg. Kenderong. The photograph was taken by author ZMI

associated with knowledge, attitude, and practice regarding malaria among indigenous Orang Asli communities in Pos Lenjang is presented in Tables 4, 5, and 6, respectively. In Table 4, several variables were found to be significantly associated with good knowledge, including primary education (crude odds ratio [cOR] = 2.43; 95% CI 1.25–4.72; p = 0.009), secondary education (cOR = 2.22; 95% CI 1.19–4.15; p = 0.012), previous malaria infection (cOR = 5.23; 95% CI 2.27–12.75; p < 0.001), and unemployment (cOR = 0.26; 95% CI 0.09–0.77; p = 0.015). Additionally, Table 5 shows that secondary education (cOR = 3.34; 95% CI 1.76–6.20; p < 0.001), previous malaria infection (cOR = 2.56; 95% CI 1.19–5.54; p = 0.017), and unemployment (cOR = 0.29; 95% CI 0.10–0.81; p = 0.018) were significant risk factors for a good attitude towards malaria. For practice, significant predictors of good practice regarding malaria were age between 40 and 59 years (cOR = 3.04; 95% CI 1.04–8.87; p = 0.042), secondary education (cOR = 0.42; 95% CI 0.18–0.98; p = 0.044), and involvement in collecting forest products (cOR = 0.29; 95% CI 0.09–1.00; p = 0.049), as shown in Table 6.

Table 7 shows the final multivariate logistic regression analysis for predictors of participants' levels of knowledge, attitude, and practice regarding malaria among the communities. The results indicated that individuals aged between 40 and 59 years (adjusted odds ratio [aOR] = 6.90; 95% CI 1.16–41.02; p = 0.034), those with primary education (aOR = 2.67; 95% CI 1.21–5.89; p = 0.015) or secondary education (aOR = 2.75; 95% CI 1.18–6.39; p = 0.019), and those with a history of malaria (aOR = 5.14; 95% CI 2.06–12.85; p < 0.001) were significantly more likely to have good knowledge about malaria. Significantly higher odds of a good attitude were also found in those with secondary education (aOR = 4.05; 95% CI 1.78–9.21; p < 0.001) and a previous history of malaria (aOR = 2.74; 95% CI 1.20–6.26; p = 0.017). Conversely, lower odds were observed for the unemployed (aOR = 0.25; 95% CI 0.08–0.79; p = 0.018) and those involved in collecting forest products (aOR = 0.25;

Table 2 Participant knowledge on the cause of malaria, signs and symptoms, prevention methods and care-seeking behaviour

Variable	Category	Frequency	Percentage (%)
Know the cause of malaria, n (%)	Yes	123	46.1
	No	144	53.9
Type source of malaria, n (%)	Mosquito bite	101	82.1
	Stagnant water	12	9.8
	Dirty surrounding	7	5.7
	Poor nutrition	1	0.8
	Contact with a malaria patient	2	1.6
Know symptoms of malaria, n (%)	Yes	137	51.3
	No	130	48.7
Symptoms of malaria[a], n (%)	Fever	96	30.6
	Headache	61	19.4
	Rigor/chills	111	35.4
	Body ache	30	9.6
	Nausea	8	2.5
	Vomiting	1	0.3
	Diarrhea	7	2.2
Know prevention of malaria, n (%)	Yes	140	52.4
	No	127	47.6
Prevention of malaria[a], n (%)	Sleep under a bed net	102	58.6
	Indoor residual spray	16	9.2
	Take medication	6	3.4
	Wear protective clothing	1	0.6
	Burn mosquito coils	4	2.3
	Drain stagnant water	38	21.8
	Wear insect repellent	2	1.2
	Avoid mosquito biting time	3	1.7
	Avoid contact with a malaria patient	2	1.2
Know practice on managing illness, n (%)	Yes	242	90.6
	No	25	9.4
Practice on managing illness[a], n (%)	Go to the clinic immediately	232	93.9
	Purchase medication from the local shop	1	0.4
	Seek treatment from a traditional healer	11	4.5
	Wait out the symptoms until well	3	1.2
Level of knowledge[b]	Good	132	49.4
	Poor	135	50.6
Level of prevention practice[c]	Good	222	83.1
	Poor	45	16.9

[a] Some respondents answered more than one answer

[b] Level of knowledge was determined based on knowledge score by summing up the score for knowledge on cause of malaria, signs and prevention, then categorized according to the median of the total score

[c] Defined based on ITNs utilization and usage frequency

95% CI 0.61–0.99; p = 0.049) for attitude and practice, respectively.

Discussion

In Malaysia, despite achieving zero indigenous human malaria cases, efforts to eliminate the disease are being hindered by the rising number of human cases of zoonotic malaria, which the WHO has declared a public health threat [18]. Therefore, understanding the knowledge, attitudes, and practices (KAP) among susceptible and vulnerable Malaysians towards malaria is crucial. Indigenous populations, such as the Orang Asli of Peninsular Malaysia, are often at higher risk due to their proximity to forested areas where both human and zoonotic

Table 3 Participant attitude towards malaria

Attitude	Totally agree, n (%)	Agree, n (%)	Neutral, n (%)	Disagree, n (%)	Totally disagree, n (%)
Everybody can have malaria	75 (28.1)	47 (17.6)	86 (32.2)	49 (18.4)	10 (3.7)
Malaria is deadly	170 (63.7)	67 (25.1)	30 (11.2)	0 (0)	0 (0)
Malaria can be cured with medical treatment	159 (59.6)	70 (26.2)	25 (9.4)	3 (1.1)	10 (3.7)
Malaria can be prevented	129 (48.3)	79 (29.6)	45 (16.9)	8 (3.0)	6 (2.2)
It is important to be tested before taking malaria treatment	133 (49.8)	87 (32.6)	34 (12.7)	8 (3.0)	5 (1.9)
It is necessary to finish malaria treatment	194 (72.7)	49 (18.4)	20 (7.5)	4 (1.4)	0 (0)
Level of attitude[a]					
Positive	145 (54.3)				
Negative	122 (45.7)				

[a] Sum of scores across the scale was used to measure attitude and categorized based on the median of the total score

Table 4 Univariate analysis for predictors of participant's level of knowledge on malaria

Variable	Category	Good knowledge	Poor knowledge	cOR (95% CI)	p-value
Age group, n (%), years	12–18	15 (42.9)	20 (57.1)	1	
	19–39	65 (51.2)	62 (48.8)	1.40 (0.66–2.97)	0.384
	40–59	49 (54.4)	41 (45.6)	1.59 (0.73–3.50)	0.246
	≥ 60	3 (20)	12 (80)	0.33 (0.08–1.40)	0.132
Gender, n (%)	Female	70 (49.6)	71 (50.4)	1	
	Male	62 (49.2)	64 (50.8)	0.98 (0.61–1.59)	0.299
Education level, n (%)	No formal education	23 (33.8)	45 (66.2)	1	
	Primary	46 (55.4)	37 (44.6)	2.43 (1.25–4.72)	0.009
	Secondary	59 (53.2)	52 (46.8)	2.22 (1.19–4.15)	0.012
	Tertiary	4 (80)	1 (20)	7.83 (0.83–74.12)	0.073
Monthly income (MYR), n (%)	≤ 500	122 (48.4)	130 (51.6)	1	
	> 500	10 (66.7)	5 (33.3)	2.13 (0.71–6.41)	0.178
Previous history of malaria, n (%)	No	102 (44.3)	128 (55.7)	1	
	Yes	30 (81.1)	7 (18.9)	5.38 (2.27–12.75)	< 0.001
Occupation, n (%)	Agriculture	60 (56.1)	47 (43.9)	1	
	Collect forest product	4 (28.6)	10 (71.4)	0.31 (0.09–1.06)	0.062
	Formal employment	8 (66.7)	4 (33.3)	1.57 (0.45–5.52)	0.485
	Housewife	40 (44.9)	49 (55.1)	0.64 (0.36–1.13)	0.121
	Student	15 (60)	10 (40)	1.18 (0.48–2.85)	0.721
	Unemployed	5 (25)	15 (75)	0.26 (0.09–0.77)	0.015

cOR crude odd ratio, *CI* confidence interval, *MYR* Malaysian Ringgit

malaria persist. Ongoing KAP studies ensure that preventive measures are culturally appropriate and effective, sustaining the malaria-free status and addressing potential outbreaks swiftly. In this study, an investigation was conducted on the KAP regarding malaria among the indigenous settlement of the Semai sub-ethnic group from the Senoi indigenous Orang Asli in Pahang, Peninsular Malaysia. The results provide evidence that the level of knowledge and attitude regarding malaria was low in the communities; however, surprisingly, the level of practice was high. These findings could shed light on a potential gap between knowledge/attitude and actual behaviour regarding malaria prevention and control among the Senoi indigenous Orang Asli communities. Despite the low level of knowledge and attitude, the high level of practice indicates that there may be other factors motivating the community to engage in preventive practices.

Table 5 Univariate analysis for predictors of participant's level of attitude toward malaria

Variable	Category	Good attitude	Poor attitude	cOR (95% CI)	p-value
Age group, n (%), years	12–18	16 (45.7)	19 (54.3)	1	
	19–39	77 (60.6)	50 (39.4)	1.83 (0.86–3.89)	0.117
	40–59	44 (48.9)	46 (51.1)	1.14 (0.52–2.49)	0.75
	≥ 60	8 (53.3)	7 (46.7)	1.36 (0.40–4.57)	0.622
Gender, n (%)	Female	71 (51.1)	69 (48.9)	1	
	Male	145 (73.2)	53 (26.8)	1.32 (0.81–2.14)	0.261
Education level, n (%)	No formal education	25 (36.8)	43 (63.2)	1	
	Primary	43 (51.8)	40 (48.2)	1.85 (0.96–3.56)	0.066
	Secondary	73 (65.8)	38 (34.2)	3.34 (1.76–6.20)	< 0.001
	Tertiary	4 (80)	1 (20)	6.88 (0.73–65.02)	0.092
Monthly income (MYR), n (%)	≤ 500	133 (52.8)	119 (47.2)	1	
	> 500	12 (80)	3 (20)	3.58 (0.99–12.99)	0.053
Previous history of malaria, n (%)	No	118 (51.3)	112 (48.7)	1	
	Yes	27 (73)	10 (27)	2.56 (1.19–5.54)	0.017
Occupation, n (%)	Agriculture	64 (59.8)	43 (40.2)	1	
	Collect forest product	7 (50)	7 (50)	0.67 (0.22–2.05)	0.485
	Formal employment	9 (75)	3 (25)	2.02 (0.52–7.87)	0.313
	Housewife	45 (50.6)	44 (49.4)	0.69 (0.39–1.21)	0.195
	Student	14 (56)	11 (44)	0.86 (0.36–2.06)	0.727
	Unemployed	6 (30)	14 (70)	0.29 (0.10–0.81)	0.018

cOR crude odd ratio, *CI* confidence interval, *MYR* Malaysian Ringgit

Table 6 Univariate analysis for predictors of participant's level of practice on malaria

Variable	Category	Good practice	Poor practice	cOR (95% CI)	p-value
Age group, n (%), years	12–18	27 (77.1)	8 (22.9)	1	
	19–39	103 (81.1)	24 (18.9)	1.27 (0.51–3.15)	0.603
	40–59	82 (91.1)	8 (8.9)	3.04 (1.04–8.87)	0.042
	≥ 60	10 (66.7)	5 (33.3)	0.59 (0.16–2.25)	0.441
Gender, n (%)	Female	121(85.8)	20 (14.2)	1	
	Male	101 (80.2)	25 (19.8)	0.67 (0.35–1.27)	0.22
Education level[a], n (%)	No formal education	60 (88.2)	8 (11.8)	1	
	Primary	73 (88)	10 (12)	0.97(0.36–2.62)	0.957
	Secondary	84 (75.7)	27 (24.3)	0.42 (0.18–0.98)	0.044
Monthly income (MYR), n (%)	≤ 500	209 (82.9)	43 (17.1)	1	
	> 500	13 (86.7)	2 (13.3)	1.34 (0.29–6.14)	0.709
Previous history of malaria, n (%)	No	191 (83)	39 (17)	1	
	Yes	31 (83.8)	6 (16.2)	1.06 (0.41–2.7)	0.991
Occupation, n (%)	Agriculture	92 (86)	15 (14)	1	
	Collect forest product	9 (64.3)	5 (35.7)	0.29 (0.09–1.0)	0.049
	Formal employment	10 (83.3)	2 (16.7)	0.82 (0.16–4.09)	0.804
	Housewife	76 (85.4)	13 (14.6)	0.95 (0.43–2.13)	0.907
	Student	21 (84)	4 (16)	0.86 (0.26–2.84)	0.800
	Unemployed	14 (70)	6 (30)	0.38 (0.13–1.14)	0.085

cOR crude odd ratio, *CI* confidence interval, *MYR* Malaysian Ringgit

[a] Education level (tertiary) was excluded in the analysis as no data was available

Table 7 Multivariate analysis for predictors of participant's level of knowledge, attitude and malaria on malaria

Variable	Associated factor	aOR (95% CI)	p-value
Knowledge	Age (40–59 years old)	6.90 (1.16–41.02)	0.034
	Education level (primary)	2.67 (1.21–5.89)	0.015
	Education level (secondary)	2.75 (1.18–6.39)	0.019
	Previous history of malaria (yes)	5.14 (2.06–12.85)	< 0.001
Attitude	Education level (secondary)	4.05 (1.78–9.21)	< 0.001
	Previous history of malaria (yes)	2.74 (1.20–6.26)	0.017
	Occupation (unemployed)	0.25 (0.08–0.79)	0.018
Practice	Occupation (collect forest products)	0.25 (0.61–0.99)	0.049

aOR adjusted odd ratio, *CI* confidence interval

Knowledge about malaria is crucial because it empowers individuals to take preventive measures, seek timely treatment, and reduce the spread of the disease within their communities. In this study, most of the participants acknowledged mosquito bites as the mode of transmission for malaria, aligning with other reports [6, 19, 20]. This correct identification is crucial for effective prevention and marks a significant improvement from earlier studies among the Orang Asli in Peninsular Malaysia, where many participants demonstrated misconceptions about the transmission of malaria [14]. Rigour and fever were the most commonly reported symptoms, consistent with other studies [6, 15, 19–21]. Despite this, the overall knowledge score about malaria transmission, symptoms, and preventive measures remained low among the study participants (49.4%). The reason could be limited access to accurate and up-to-date information about malaria in the communities studied, leading to misconceptions or outdated beliefs about the disease. Cultural beliefs and practices might also influence the perception of malaria, potentially hindering the adoption of preventive measures or prompt treatment-seeking behaviours. Addressing these factors through targeted education campaigns and community engagement could help improve knowledge and mitigate the impact of malaria in Orang Asli populations.

Furthermore, participants with primary and secondary education were twice as likely to have good knowledge about malaria, likely due to better access to health information and malaria control programs, even in remote areas [15, 22, 23]. A previous history of malaria infection was also associated with better knowledge, as those previously infected received health education during treatment, highlighting the role of personal experience in shaping health knowledge and attitudes [14]. This education may have included information about malaria transmission, symptoms, and preventive measures, which could contribute to their better knowledge about the disease compared to those who have not been infected. Having experienced the symptoms and consequences of malaria firsthand, individuals may be more motivated to learn about the disease and how to prevent future infections, leading to a better understanding of malaria. Additionally, participants aged 40 and above had better knowledge, possibly due to greater exposure to health promotion campaigns during their youth when malaria incidence was higher [24, 25]. Individuals in the older age group might be more proactive about seeking health-related information as they approach or experience common health issues associated with ageing [6], prompting them to learn more about diseases like malaria and how to prevent them.

The current findings also reveal that the overall good attitudes score towards malaria was less than 60%, indicating a low attitude among the communities. A majority of participants believed that only certain groups could get infected by malaria by chance, whereas in reality, everyone is at risk. These findings contradict the results of previous studies where the majority agreed that everyone is at risk of contracting malaria [15, 20]. This misconception could lead to participants neglecting malaria preventive measures, as they believe they are not at risk. However, attitudes towards malaria prevention, diagnosis, and treatment were promising. Education level and previous history of malaria were positively associated with good attitudes toward malaria. Participants with a secondary education level were found to be four times more likely to have good attitudes regarding malaria compared to illiterates. This aligns with other studies that show positive attitudinal changes are associated with the level of education received by participants [15]. A higher level of education fosters critical thinking and health-seeking behaviour, making educated individuals more likely to adopt and adhere to preventive measures. For instance, a study by Djoufounna et al. found that higher educational attainment was significantly associated with increased knowledge and proactive attitudes towards malaria prevention [23]. Similarly, Raghupathi et al. reported that educated individuals were more likely to engage in community health initiatives and utilize healthcare services effectively [26]. Therefore, enhancing attitudes toward malaria among indigenous Orang Asli people is vital for increasing their engagement in prevention and treatment measures, thereby decreasing the disease's prevalence and impact in their communities.

It was also found that those who were unemployed had significantly associated with low odds of having positive attitudes toward malaria. Unemployed individuals often face significant economic hardships, leading to limited

access to health information and resources necessary for effective malaria prevention [27]. Economic constraints can make it difficult for them to prioritize preventive measures or attend health education sessions. The unemployed are often less educated and poorer, lacking the ability to pay out-of-pocket for cost associated with seeking treatment for illness. Previous studies show that willingness to pay is closely related to socioeconomic status which is a major health determinant [28, 29]. Moreover, unemployment is associated with lower educational attainment, further reducing awareness and understanding of malaria risks and prevention strategies [30]. Thus, social determinants such as poverty make it harder for unemployed individuals to adopt positive attitudes towards malaria prevention.

In terms of care-seeking management, most of the participants reported that they would seek treatment immediately at the clinic. This finding aligns with many other studies where prompt treatment is essential in eliminating the *Plasmodium* parasite from the bloodstream and preventing complications [15, 19, 20, 22]. The evolution of Orang Asli's perception of treatment-seeking behaviour shows marked positive changes compared to the previous KAP study done among the Orang Asli 14 years ago, where the majority of indigenous people were more inclined to opt for traditional healers instead of visiting health facilities at that time [14]. The increased number of health facilities and accessibilities, accompanied by extensive health education and promotion, might contributed to the change in the behaviour. Specifically, in Pos Lenjang, the presence of a rural community clinic acts as a positive factor for the indigenous Orang Asli people to seek prompt treatment for all illnesses including malaria. Apart from that, regular visits by a dedicated mobile health team to the villages play a major role in improving health-seeking behaviour among the communities.

The present study also showed that the overall level of practice in malaria prevention was high (83.1%) among participants in Pos Lenjang. However, a gap was identified while a majority (84.3%) reported using ITNs at night, 58.6% knew that bed nets are a means of malaria prevention. The mass distribution of ITNs by the health authorities in Kuala Lipis likely contributes to the high possession and utilization rates in the community, but increasing sensitization and awareness of their benefits is needed to ensure continued use. This study also highlighted that high levels of malaria prevention practice can occur despite low to moderate levels of knowledge and attitudes towards malaria, which contradicts findings from other research showing that low levels of knowledge and attitudes typically result in low prevention practices among the community [15]. Conversely, some studies found high levels of knowledge and attitudes but low practice levels [19, 31–33]. It is a common practice for Orang Asli living in wooden or bamboo houses to use bed nets (ITN and non-ITN) while sleeping as the open eaves and gaps in the wall allow the mosquitoes to enter the house and bite the host during sleep, hence the practice has become an integral part of living among the community members [34]. Even though this study shows a high utilization rate of using the ITN, malaria transmission still occurs in the study area. It is important to note apart from ITN coverage, other factors such as the condition of the bed net, the number of people per bed net and the effectiveness of the impregnated insecticide influenced the degree of protection against the vector [35], therefore future implementation study on ITN is suggested. High levels of good practices suggest that effective practice can be achieved through public health interventions and community engagement, even with moderate knowledge and attitudes. One interesting finding was that forest product collectors had lower odds of adopting good malaria prevention practices, likely due to the nature of their occupation requiring overnight stays in the forest, bringing and making bed net use troublesome. This result aligns with a study done in Indonesia which found that the forest-goer groups had a higher risk of malaria but with relatively low uptake prevention practice [36]. Future research should explore detailed information on the behaviour of this target group, as they pose a major challenge in achieving the malaria elimination goal.

The strength of this study lies in its sampling method. Random sampling was used for sample selection, which reduces selection bias hence and allows the results to be confidently generalized to the study population. Additionally, the findings contribute to the limited body of literature on KAP regarding malaria among the hard-to-reach indigenous population in Peninsular Malaysia. However, some caveats should be considered. The quantitative nature of this study limits the understanding of in-depth reasoning and explanations related to malaria KAP. Further research using a qualitative approach is suggested for a better situational understanding of malaria in the study population. Moreover, the selection of six out of thirteen villages in the study setting limits the generalization of the results to the whole area. Hilly geographical terrain and exhaustive resource allocation pose a huge challenge if the research is to be conducted in all thirteen villages. Another limitation is the use of self-reported questionnaires, which are subjected to recall bias and social desirability bias.

Conclusion

This study provides evidence that although the overall level of knowledge and attitude regarding malaria is low, the level of malaria prevention practice among the indigenous Orang Asli of Pos Lenjang in Pahang is high. The education level and previous history of contracting malaria among respondents are positively associated with good knowledge and attitudes towards malaria. However, the majority of the study population remains unaware that the risk of contracting malaria is not limited to certain groups of people by chance. Besides that, only a slight majority of the respondents who use ITN understand its purpose. This lack of knowledge poses a risk of careless attitudes in practising effective malaria prevention measures and needs to be addressed. Interestingly, it was also observed that alongside the unemployed, respondents who forage in the forest are found to have lower odds of adopting good malaria prevention practices. The behaviour of this group must be studied further, as it potentially hinders the progress of malaria control and elimination strategies.

Abbreviations

BFMP	Blood film for malaria parasite
CI	Confident interval
IQR	Interquartile range
IRS	Indoor residual spraying
ITN	Insecticide-treated nets
KAP	Knowledge, attitude and practice
MYR	Malaysian Ringgit
OR	Odd ratio
WHO	World Health Organization

Acknowledgements

We would like to extend our gratitude to the communities and community leaders for their support and participation in the surveys. We wish to sincerely thank all members of the field team. We also thank the Director-General of Health, Malaysia for the permission to publish this article.

Author contributions

LS, MFMJ, MKAK, NNMN, SAS and ZMI conceived and designed the study. LS, MFMJ, MKAK, NNMN, NAMS, MRAR and ZMI performed the fieldwork. LS, MFMJ, MKAK, KS and ZMI performed data cleaning and analysed the data. LS, MFMJ, MKAK, KS and ZMI interpreted the data. LS wrote the first draft of the manuscript. WRWI, JZT and ZMI provided critical revision of the manuscript for important intellectual content. All authors read and approved the final manuscript.

Funding

This work was supported by internal funding from Lipis District Health Office, Kuala Lipis, Pahang. ZMI was supported by Geran Ganjaran Penerbitan (GP-K019336) from Universiti Kebangsaan Malaysia.

Availability of data and materials

The dataset used and/or analysed during the current survey are available from the corresponding authors upon request.

Declarations

Ethics approval and consent to participate

The study was approved by the Medical Research Ethics Committee of the National Institute of Health Malaysia (Reference no. NMRR ID-24-00476-KIE) and the Department of Orang Asli Development, Ministry of Rural and Regional Development Malaysia (Reference no. JAKOA.PP.R.004 JLD 5(48)). Written informed consent was obtained from all participants in this study.

Consent for publication

All authors approved the final draft for journal submission.

Competing interests

The authors declare no competing interests.

Author details

[1]Lipis District Health Office, Kuala Lipis, Pahang, Malaysia. [2]Department of Parasitology and Medical Entomology, Faculty of Medicine, Universiti Kebangsaan Malaysia, Cheras, Kuala Lumpur, Malaysia. [3]National Public Health Laboratory, Ministry of Health, Sungai Buloh, Selangor, Malaysia. [4]Pahang State Health Department, Bandar Indera Mahkota, Kuantan, Pahang, Malaysia. [5]Vector Borne Disease Sector, Ministry of Health, Putrajaya, Malaysia.

Received: 15 July 2024 Accepted: 23 August 2024
Published online: 05 September 2024

References

1. WHO. World Malaria Report 2023. Geneva: World Health Organization; 2023. https://www.who.int/publications/i/item/9789240086173
2. Dian ND, Rahim MAFA, Chan S, Idris ZM. Non-human primate malaria infections: a review on the epidemiology in Malaysia. Int J Environ Res Public Health. 2022;19:7888.
3. Muhammad A, Azman E, Eddie N, Azmi N, Yee V, Idris ZM. The rise of *Plasmodium knowlesi* cases: implication to Malaysia's malaria-free status. Asian Pac J Trop Med. 2022;15:337–8.
4. Shah NM, Rus RC, Mustapha R, Hussain MAM, Wahab NA. The Orang Asli profile in Peninsular Malaysia: background & challenges. Int J Acad Res Bus Soc Sci. 2018;8:1157–64.
5. Xuan-Rong Koh D, Zailani MAH, Raja Sabudin RZA, Muniandy S, Muhamad Hata NAA, Mohd Noor SNB, et al. Prevalence and molecular heterogeneity of glucose-6-phosphate dehydrogenase (G6PD) deficiency in the Senoi Malaysian Orang Asli population. PLoS ONE. 2023;18:e0294891.
6. Munajat MB, Rahim MAFA, Wahid W, Seri Rakna MIM, Divis PCS, Chuangchaiya S, et al. Perceptions and prevention practices on malaria among the indigenous Orang Asli community in Kelantan, Peninsular Malaysia. Malar J. 2021;20:202.
7. Dian ND, Muhammad AB, Azman EN, Eddie NA, Azmi NI, Yee VCT, et al. Evidence of submicroscopic *Plasmodium knowlesi* mono-infection in remote indigenous communities in Kelantan, Peninsular Malaysia. Am J Trop Med Hyg. 2023;109:1081–5.
8. Rahim MAFA, Munajat MB, Dian ND, Seri Rakna MIM, Wahid W, Ghazali N, et al. Naturally acquired antibody response to *Plasmodium falciparum* and *Plasmodium vivax* among indigenous Orang Asli communities in Peninsular Malaysia. Front Cell Infect Microbiol. 2023;13:1165634.
9. Mat Salleh NH, Abdul Rahman MF, Samsusah S, De Silva JR, Tan JH, Amir A, et al. Complications of sub-microscopic *Plasmodium vivax* malaria among Orang Asli in Pos Lenjang, Kuala Lipis. Trop Biomed. 2021;38:33–5.
10. Ali WN, Ahmad R, Nor ZM, Ismail Z, Lim LH. Population dynamics of adult mosquitoes (Diptera: Culicidae) in malaria endemic villages of Kuala Lipis, Pahang, Malaysia. Southeast Asian J Trop Med Public Health. 2011;42:259–67.
11. Ahmad R, Ali WN, Nor ZM, Ismail Z, Hadi AA, Ibrahim MN, et al. Mapping of mosquito breeding sites in malaria endemic areas in Pos Lenjang, Kuala Lipis, Pahang, Malaysia. Malar J. 2011;10:361.
12. Millat-Martínez P, Gabong R, Balanza N, Luana S, Sanz S, Raulo S, et al. Coverage, determinants of use and repurposing of long-lasting insecticidal nets two years after a mass distribution in Lihir Islands, Papua New Guinea: a cross-sectional study. Malar J. 2021;20:336.
13. Chourasia MK, Raghavendra K, Bhatt RM, Swain DK, Valecha N, Kleinschmidt I. Burden of asymptomatic malaria among a tribal population in a forested village of central India: a hidden challenge for malaria control in India. Public Health. 2017;147:92–7.

14. Al-Adhroey AH, Nor ZM, Al-Mekhlafi HM, Mahmud R. Opportunities and obstacles to the elimination of malaria from Peninsular Malaysia: knowledge, attitudes and practices on malaria among aboriginal and rural communities. Malar J. 2010;9:137.
15. Tairou F, Nawaz S, Tahita MC, Herrera S, Faye B, Tine RCK. Malaria prevention knowledge, attitudes, and practices (KAP) among adolescents living in an area of persistent transmission in Senegal: results from a cross-sectional study. PLoS ONE. 2022;17: e0274656.
16. Krejcie RV, Morgan DW. Determining sample size for research activities. Educ Psychol Meas. 1970;30:607–10.
17. Lopez AR, Brown CA. Knowledge, attitudes and practices regarding malaria prevention and control in communities in the Eastern Region, Ghana, 2020. PLoS ONE. 2023;18: e0290822.
18. WHO. World Malaria Report 2021. Geneva: World Health Organization; 2021. https://www.who.int/teams/global-malaria-programme/reports/world-malaria-report-2021
19. Rahim MAFA, Chuangchaiya S, Chanpum P, Palawong L, Kantee P, Dian ND, et al. Seroepidemiological surveillance, community perceptions and associated risk factors of malaria exposure among forest-goers in Northeastern Thailand. Front Cell Infect Microbiol. 2022;12: 953585.
20. Saha A, Sarker M, Kabir M, Lu G, Müller O. Knowledge, attitudes, and practices regarding malaria control among the slash and burn cultivators in Rangamati Hill tracts of Bangladesh. Malar J. 2019;18:216.
21. Abdul Rahim FA, Md Yatim MF, Abdul Mutalip MH, Mahmud MAF. Assessing the population's correct knowledge of malaria in Malaysia: a vital component for malaria elimination certification. Malar J. 2023;22:267.
22. Nejati J, Moosa-Kazemi SH, Saghafipour A, Soofi K. Knowledge, attitude and practice (KAP) on malaria, from high malaria burden rural communities, southeastern Iran. J Parasit Dis. 2018;42:62–7.
23. Djoufounna J, Bamou R, Mayi MPA, Kala-Chouakeu NA, Tabue R, Awono-Ambene P, et al. Population knowledge, attitudes and practices towards malaria prevention in the locality of Makenene, Centre-Cameroon. Malar J. 2022;21:234.
24. Abbas F, Kigadye E, Mohamed F, Khamis M, Mbaraka J, Serbantez N, et al. Socio-demographic trends in malaria knowledge and implications for behaviour change interventions in Zanzibar. Malar J. 2023;22:39.
25. Liheluka EA, Massawe IS, Chiduo MG, Mandara CI, Chacky F, Ndekuka L, et al. Community knowledge, attitude, practices and beliefs associated with persistence of malaria transmission in North-western and Southern regions of Tanzania. Malar J. 2023;22:304.
26. Raghupathi V, Raghupathi W. The influence of education on health: an empirical assessment of OECD countries for the period 1995–2015. Arch Public Health. 2020;78:20.
27. Ricci F. Social implications of malaria and their relationships with poverty. Mediterr J Hematol Infect Dis. 2012;4: e2012048.
28. Uzochukwu BS, Onwujekwe OE, Uguru NP, Ughasoro MD, Ezeoke OP. Willingness to pay for rapid diagnostic tests for the diagnosis and treatment of malaria in southeast Nigeria: ex post and ex ante. Int J Equity Health. 2010;9:1.
29. Singh MP, Saha KB, Chand SK, Sabin LL. The economic cost of malaria at the household level in high and low transmission areas of central India. Acta Trop. 2019;190:344–9.
30. Degarege A, Fennie K, Degarege D, Chennupati S, Madhivanan P. Improving socioeconomic status may reduce the burden of malaria in sub Saharan Africa: a systematic review and meta-analysis. PLoS ONE. 2019;14: e0211205.
31. DePina AJ, Dia AK, de Ascenção Soares Martins A, Ferreira MC, Moreira AL, Leal SV, et al. Knowledge, attitudes and practices about malaria in Cabo Verde: a country in the pre-elimination context. BMC Public Health. 2019;19:850.
32. Kala Chouakeu NA, Ngingahi LG, Bamou R, Talipouo A, Ngadjeu CS, Mayi MPA, et al. Knowledge, attitude, and practices (KAP) of human populations towards malaria control in four ecoepidemiological settings in Cameroon. J Trop Med. 2021;2021:9925135.
33. Forero DA, Chaparro PE, Vallejo AF, Benavides Y, Gutiérrez JB, Arévalo-Herrera M, et al. Knowledge, attitudes and practices of malaria in Colombia. Malar J. 2014;13:165.
34. Naserrudin NA, Hod R, Jeffree MS, Ahmed K, Hassan MR. The emerging threat of *Plasmodium knowlesi* malaria infection: a concept paper on the vulnerable factors in human. Int J Environ Res Public Health. 2022;19:4419.
35. Kaur G. Predictors of malaria among Malaysian aborigines. Asia Pac J Public Health. 2009;21:205–15.
36. Gallalee S, Zarlinda I, Silaen MG, Cotter C, Cueto C, Elyazar IRF, et al. Forest-goers as a heterogeneous population at high-risk for malaria: a case-control study in Aceh Province, Indonesia. Malar J. 2024;23:37.

Publisher's Note