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Modeling Malaria Risk Factors by Logistic Regression Among Hilly Communities in Rural East Nusa Tenggara Province, Indonesia

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ABSTRACT

Malaria is a global health problem, including in Indonesia. Currently, the highest malaria burden is in the eastern part of the country, particularly in East Nusa Tenggara Province (ENTP). Disparities in malaria risk factors among different geographical settings are significant. However, modeling the effect of malaria knowledge levels on malaria risk factors for rural hilly communities has not been investigated yet. This study used data from 986 rural adults living in hilly areas of ENTP. Data on malaria history of participants, their various demographic, environmental and behavioral aspects of malaria were collected. Modeling was performed by using a logistic regression model. This study found that the prevalence of malaria history in hilly communities was 11.4%. The prevalence was significantly higher among those with no education (adjusted odds ratio (AOR): 2.614, 95% confidence interval (CI): 1.428– 4.787) compared to those with at least a junior high school education; a low level of malaria knowledge (AOR: 2.181 with 95% CI: 1.045– 4.552) compared to those with a high-level malaria knowledge; non-use of bed nets (AOR: 2.001 with 95% CI: 1.219– 3.286) compared to their counterpart. Malaria health interventions and malaria knowledge modules in the local curriculum are critical to achieving the achievement of malaria elimination by 2030 in ENTP.

1. INTRODUCTION

Malaria is a global health problem distributed across 85 countries, particularly in the sub-tropical and tropical nations [1]. The current data estimates that the number of malaria cases is about 249 million of which 94% of this total number is in the African continent and about 2% is contributed from countries in the Southeast Asian (SEA) Region [1]. The leaders of the region are committed to achieving a malaria-free zone by 2030. Two countries in the region, the Maldives and Sri Lanka, have been declared malaria-free since 2015 and 2016 respectively [2]. The number of malaria cases and deaths due to malaria has shown a significant downward trend in the last two decades. By 2022, it was estimated that there will be 8000 cases of malaria deaths in the Southeast Asian Region, of which about 94% of this total is contributed by India and Indonesia [1].

In line with the global commitment, Indonesia is also moving towards achieving malaria elimination, which is targeted to occur by 2030 [3]. Malaria elimination means no local cases of malaria transmission within a certain geographical area for three consecutive years [1, 2]. To date, much success has been achieved in realizing this commitment. By 2023, 75.7% of the total number of districts and municipalities in the country (389 out of 514 districts and municipalities in the country) had been classified as malaria elimination status [4]. However, this progress shows a huge disparity between Western and Eastern parts of the country. Generally, the districts in the Western part of Indonesia have been declared malaria-free area and even all districts in eight provinces in the Western part have achieved malaria elimination, whilst all districts in five provinces in the Eastern region have not achieved malaria elimination zone and many districts in this region have not yet achieved malaria elimination area status including in East Nusa Tenggara Province (ENTP) [4].

ENTP is an archipelago province with 21 districts and one municipality spreading across six major islands: Flores, Sumba, Timor, Alor, Lembata and Sabu Raijua [5]. To determine the burden of malaria in each district and following the national guidelines, all districts in the province were grouped based on the Annual Parasite Incidence (API) value per 1000 population (‰). The areas with API greater than 5‰ were categorized as high endemic areas, areas with API of 1-5‰ were grouped into medium endemic areas, and areas with API < 1‰ were grouped into low endemic areas. Then, if there is no local malaria transmission for 3 consecutive years, it is classified as a malaria-free area [3]. To date, a total of 9 districts have achieved malaria-free status, while the others are 6 districts with moderate endemic status, 4 districts with low endemic status, and 3 districts with high endemic status. In 2023, the total number of malaria cases in ENTP was 6931 [5]. Malaria patients in this region are generally caused by plasmodium falciparum, but the number of malaria patients caused by plasmodium vivax is also quite high in this region [6-8]. This would provide its own challenges in the efforts to achieve malaria elimination because the complete treatment of patients with the plasmodium vivax type requires high awareness from the public to consume the medication completely for 14 days [9, 10].

Malaria is a very complex problem because it is related to many aspects, especially environmental factors [11-13], changes in weather aspects [14-16], the type of plasmodium that causes malaria [17-19], socio-demographic conditions of the local community [20-22] and also community behavior in preventing and seeking treatment for malaria [23, 24]. In carrying out modeling to obtain risk factors for malaria, the various factors above should be considered to be included in the model because the risk of malaria shows different variations between these factors in various environmental conditions [25].

History of malaria incidents is an example of a dichotomous variable, meaning a variable that has two categories, whether someone has an experience with malaria or not. One analytical method for modeling the outcome variable having categories, such as success or failure, having a history of certain diseases or not, is the logistic regression method [26, 27]. Modeling using binary logistic regression has been widely used to estimate malaria risk factors both at the global level [22, 28-30] and in Indonesian context [31-34]. At the global level, it was found that the use of a binary logistic regression model was able to show that the risk of malaria incidence varies within each age group [29], types of work have different risks for malaria incidence [22], environmental conditions around the home have a significant effect on malaria incidence [28, 30]. Logistic regression modeling in investigating the risk factors of malaria incidence in Indonesia has been widely carried out, for example research conducted by Hasyim et al. [21] in 3 villages in Tanjung Enim Regency, North Sumatra shows that low level of education is a risk factor for malaria incidence [21], the quality of service from health workers influences the incidence of malaria [33]. Research conducted by Sari [34] shows that the 12–25-year age group is 3 times more likely to contract malaria when compared to the ≥ 46-year age group. However, those studies using small samples and modeling malaria risk factors have not been studied thoroughly, especially for the behavioral aspects of malaria.

Furthermore, the current literature indicates that in the group of children under five, malaria prevalence and its risk factors shown a different level at various geographic heterogeneity including in coastline and highland area [35, 36], However, the effect of different level of malaria knowledge among rural adults living in highland on the malaria variation has not been investigated in those studies. Investigating rural adults is critical for the Indonesian context, as a high burden of malaria is contributed by the rural population [3]. Furthermore, the behavioral aspect of malaria, including malaria knowledge level of the local population, is critical to boost malaria elimination [37, 38]. Modelling the effect of this malaria knowledge level and other factors, including environmental, socio-demographic aspects of malaria for rural hilly communities, has not been investigated. Therefore, the researchers are interested in filling this knowledge gap by applying a logistic regression method in modeling the risk factors of malaria history among rural communities living in hilly areas in ENTP, Indonesia. It is hoped that this study will provide the baseline data to explore the variation of malaria risk factors in rural populations with different topographic settings, and also the results of this research could contribute to supporting the malaria elimination progress in ENTP Indonesia.

2. MATERIALS AND METHODS

2.1 Source of data

This study applied secondary data available from an international journal investigating the epidemiology of malaria and the behavioral aspects of malaria in rural communities of ENTP, Indonesia [39]. In those studies, data were collected based on the community-based cross-sectional study in three districts with different malaria endemic settings (MESs) representing high, moderate, and low MESs. In each MES, three sub-districts were randomly chosen. All villages in a selected sub-district participated in that study, with a total of 49 villages. In each village, 20 to 40 households were selected proportional to the village population size. The selection of the households in the visited village was done by a systematic random sampling method. In each selected household, one adult participated voluntarily as a sample of that study. As the study wanted to investigate the level of malaria knowledge among rural residents, the main criterion to be selected as a sample was healthy people aged at least 18 years old. That study satisfied the Declaration of Helsinki to protect the confidentiality, integrity, and rights of respondents with the approval of Human Ethics Committee of Swinburne University of Technology, Australia, and the Health Ministry of Indonesian Government with ethics identification number 20191428-1490 and LB.02.01/2/KE.418/2019, respectively. The total number of samples during that study was 1503 participants [24, 39]. From this number, 986 participants live in hilly areas. This number served as the total sample for this study.

2.2 Research variables

The dependent variable of study was the respondent's self-reported history of malaria and it was a type of binary variable, namely whether having malaria experience or not in the last two years. In section five of the questionnaire, it was asked "Have you ever suffered from malaria?" The response to this question was yes or no. For those answers yes labeled with one, otherwise with zero.

The independent variables of the study were 15 variables integrating socio-demographic, environmental and behavior aspects of malaria of hilly communities in ENTP. The socio-demographic variables included gender, age group, education level, main occupation, socio-economic status (SES), family size, and household income. Gender was classified as male and female; family size was grouped as less than four family members and more than four, and occupation was classified as indoor and outdoor occupation. Whilst for age group, it was categorized as < 30, 30 -39, 40-49, 50-59, > 60; for education level, it was categorized as no education, primary education, and high school or above; and for SES, it was high, average, and low SES. Previous studies indicated that being a female [40], small family size [41], high level of education [42], high socioeconomic status [20], and indoor occupation [43] were associated with low risk of malaria. Therefore, these groups could serve as a reference category on the univariate and multivariable analyses.

The environmental variables consisted of distance to the nearest health service, which is classified as 2 km or less and > 2 km; modern house having category yes or no; source of drinking water having category running tap water and open source, and access to TV having category yes or no. Behavioral aspects of malaria comprise malaria knowledge level, having categories high, medium, and low. Whilst for variables such as poor understanding of malaria treatment-seeking behaviour (MTSB), the use of bed nets, and having travel history in the last month, they had two categories which were yes or no. Literature indicated that closed to health facilities [44], having modern house and no travel history [44], having running tap water [45], having access to TV [46], using bed net during sleeping [42], no poor MTSB [47], and high level of malaria knowledge [40] reduced the likelihood to have malaria. Therefore, these groups of categorisations served as reference categories in the analysis both for bivariate and multivariable analysis.

For composite variables such as malaria knowledge level and poor MTSB, it was defined as follows. Malaria knowledge levels of participants were assessed based on the response of the participant on ten questions asking about basic understanding of malaria; knowledge on symptoms, transmission mode, prevention measures as indicated in the previous study [48]. Participants having correct answers to at least on eight questions were classified as having a high level of malaria knowledge. For those having correct answers on six or seven questions, it was categorized as a moderate level, the rest were among individuals with limited knowledge of malaria. Following the previous study, poor understanding of MTSB was defined as seeking treatment after 24 hours or at non-health facilities [10]. In section three of the questionnaire, it was asked when and where the participant sought treatment when they or their family members experienced malaria. Those answering seeking treatment after 24 hours or at non-health facilities were classified as having poor understanding of MTSB.

2.3 Data analysis stage

The data analysis began with a descriptive approach to present the percentage of participants following the studied variables [49]. This method was used to assess the distribution of respondents based on demographic, environmental and malaria behavior variables of rural hilly communities in ENTP. Then, a multicollinearity test was conducted to investigate the possibility of strong association among predictors. This could be conducted by calculating the value of Tolerance and Variance Inflation Factors (VIF) for each predictor [50] with formula

$$Tolerance = 1 - R^2 \quad (1)$$

$$VIF = \frac{1}{Tolerance} \quad (2)$$

where,

R^2 denotes the determination coefficient of the regression results of the i[th] independent variable against other independent variables. Value of Tolerance ≤ 0.1 and VIF > 10 indicated multicollinearity amongst predictors [50].

Furthermore, bivariate analysis was done to evaluate the association between the malaria history of participants with all independent variables. The hypothesis for this analysis was:

H_0: There is no significant association between malaria history and independent variables

H_1: There is a significant association between malaria history and independent variables

This hypothesis was tested based on the value of the chi-square test (χ^2). If χ_{count}^2 is greater than χ_{table}^2 or the significance value is less than 0.05, we reject the null hypothesis. The chi-square test was defined by

$$X^2 = \sum \frac{(f_0 - f_e)^2}{f_e} \quad (3)$$

where, f_0 represents the number of counted observation; f_e means the number of expected frequencies.

All predictor variables showing a significant association with a dependent variable on this bivariate analysis with p value less than 0.25 were included in the initial model of logistic regression [36]. So, we could estimate parameter model of logit function of the regression model binary logistics with 15 predictor variables as indicated in the following form:

$$g(x) = \beta_0 + \beta_1 x_1 + \cdots + \beta_{15} x_{15} \quad (4)$$

Moreover, the selection of variables included in the final model is determined using backward elimination. All predictors having significance value greater than 5% were eliminated from the model gradually [51].

The next stage is parameter test, simultaneously to assess the effect of all predictors on the dependent variable with Omnibus Test with the following hypothesis: H_0: $\beta_1 = \beta_2 = \cdots = \beta_{15} = 0$; H_1: at least there is one $\beta_i \neq 0$, for $i = 1, 2, \ldots, 15$.

The null hypothesis could be rejected if the p-value of the Omnibus test was less than or equal to 5%.

The analysis was continued by performing test of Hosmer and Lemeshow to assess the goodness of fit of the resulted model with the following hypothesis.

H_0: There is no significant disparity between the actual observation frequencies and those predicted by the model.

H_1: There is a significant disparity between the actual and predicted values.

The rejection to the null hypothesis could be done if the p-value of Hosmer and Lemeshow test was ≤ 5%. The next step is to evaluate the effect of each predictor to the dependent variable with the following hypothesis: H_0: $\beta_i = 0$; H_1= $\beta_i \neq 0, i = 1, 2, \ldots, 15$.

We could reject the null hypothesis if the value of Wald test (W) is greater than the value of chi-square table. The Wald test was defined as

$$W = \left[\frac{\hat{\beta}_i}{SE(\hat{\beta}_i)}\right]^2 \quad (5)$$

Finally, the odds ratio (OR) and 95% confidence interval (CI) for odds ratio was computed to quantify the magnitude contribution of each predictor to dependent variables with the following formula

$$OR = exp(\hat{\beta}_i) \quad (6)$$

and 95% CI of OR was computed by

$$Exp[\hat{\beta}_i \pm 1.96 * SE(\hat{\beta}_i)] \quad (7)$$

3. RESULTS

3.1 The distribution of participants based on independent variables

The distribution of research respondents based on demographic variables, environment and behavioral aspects of malaria is presented in Table 1. The total number of respondents included for this analysis was 986. Of this number, the proportion of men and women is almost equal (44.9% and 55.1% respectively). Overall, almost half of participants finished their elementary school (47%), whilst more than half of participants worked outdoors (63.3%). Almost half of the study respondents had a low level of malaria knowledge (49.7%) and more than half did not have access to TV (65.7%) and modern housing (75.6%).

Table 1. Distribution of participants based on socio-demographic, environmental and behavioral aspects of malaria of hilly communities in ENTP, Indonesia

Characteristics	n	%
Total	986	
Gender (X_1)		
Female	543	55.1
Male	443	44.9
Age group (X_2)		
> 60	135	13.7
50 - 59	200	20.3
40 - 49	240	24.3
30 - 39	272	27.6
< 30	139	14.1
Level of education (X_3)		
Junior high school or above	348	35.3
Primary school	463	47.0
No education	175	17.7
Main occupation (X_4)		
Indoor	362	36.7
Outdoor	624	63.3
Socio-economic status (X_5)		
High	111	11.3
Average	549	55.7
Low	326	33.1
Family size (X_6)		
< = 4	542	55.0
> 4	444	45.0
HH income (X_7)		
>= PMW	78	7.90
< PMW	908	92.1
Distance to the nearest health service (X_8)		
≤ 2 km	790	80.1
> 2 km	196	19.9
Modern house (X_9)		
Yes	241	24.4
No	745	75.6
Source of drinking water (X_{10})		
Running tap water	480	48.7
Open source	506	51.3
Access to TV (X_{11})		
Yes	338	34.3
No	648	65.7
Malaria knowledge level (X_{12})		
High	204	20.7
Moderate	292	29.6
Low	490	49.7
Poor understanding of MTSB (X_{13})		
No	484	49.1
Yes	502	50.9
The use of bed net (X_{14})		
Yes	839	85.1
No	147	14.9
Travel history (X_{15})		
No	937	95.0
Yes	49	5.00

3.2 Multicollinearity test

The analysis of the association among independent variables was presented in Table 2. From the table, it was evident that the value of tolerance for all predictors was greater than 0.1 and the value of VIF for all predictors was less than 10. This indicated that there were no strong associations among predictors or there was no multicollinearity among independent variables.

Table 2. Multicollinearity test among predictors

Variables	Tolerance	VIF
X_1	0.718	1.393
X_2	0.791	1.264
X_3	0.692	1.445
X_4	0.662	1.511
X_5	0.455	2.200
X_6	0.973	1.028
X_7	0.823	1.215
X_8	0.932	1.072
X_9	0.684	1.461
X_{10}	0.939	1.065
X_{11}	0.596	1.678
X_{12}	0.793	1.262
X_{13}	0.887	1.127
X_{14}	0.947	1.056
X_{15}	0.956	1.047

3.3 The association between malaria history and predictors

Chi-square testing is carried out to investigate the relationship between various independent variables and the malaria history. This could be done by calculating the value of $\chi 2$ for each variable predictor following Eq. (3). The value of the chi-square test is presented in Table 3. From this table, it was clear that the prevalence of malaria history in hilly communities of rural ENTP Indonesia was 11.4%. Furthermore, it could be seen the malaria history of hilly community in ENTP was significantly associated with the level of education (p-value < 0.001), main occupation (p-value =0.001), family size (p-value < 0.001), distance to the nearest health service (p-value = 0.001), access to television (p-value < 0.001), malaria knowledge level (p-value < 0.001), poor understanding of MTSB (p-value = 0.009), the use of bed net (p-value < 0.001), having travel history in the last one month (p-value = 0.041), income (p-value = 0.151), and age group (p-value = 0.116). Meanwhile, independent variables such as gender, social status, source of drinking water are not related to the malaria history of hilly communities in ENTP as shown in Table 3 below.

Table 3. Relationship between malaria history and socio-demographic, environmental, and behavioral aspects of malaria in hilly communities in ENTP, Indonesia

Variables	Number at Risk	Malaria History		Chi-Square Test Value	p value
		No (%)	Yes (%)		
Total	986	874 (88.6)	112 (11.4)		
Gender (X_1)					
Female	543	482 (88.8)	61 (11.2)	0.019	0.891
Male	443	392 (88.5)	51 (11.5)		
Age group (X_2)					
> 60	135	114 (84.4)	21 (15.6)	7.401	0.116
50 - 59	200	184 (92.0)	16 (8.00)		
40 - 49	240	206 (85.8)	34 (14.2)		
30 -39	272	246 (90.4)	26 (9.56)		
< 30	139	124 (89.2)	15 (10.8)		
Level of education (X_3)					
Junior high school or above	348	323 (92.8)	25 (7.18)	37.949	< 0.001
Primary school	463	419 (90.5)	44 (9.50)		
No education	175	132 (75.4)	43 (24.6)		
Main occupation (X_4)					
Indoor	362	339 (93.7)	23 (6.35)	14.233	< 0.001
Outdoor	624	535 (85.7)	89 (14.3)		
Socio-economic status (X_5)					
High	111	95 (85.6)	16 (14.4)	1.402	0.496
Average	549	491 (89.4)	58 (10.6)		
Low	326	288 (88.3)	38 (11.7)		
Family size (X_6)					
< = 4	542	498 (91.9)	44 (8.12)	12.556	< 0.001
> 4	444	376 (84.7)	68 (15.3)		
HH income (X_7)					
>= PMW	78	73 (93.6)	5 (6.41)	2.06	0.151
< PMW	908	801 (88.2)	107 (11.8)		
Distance to the nearest health service (X_8)					
<= 2 km	790	719(91.0)	71 (8.99)	22.202	< 0.001
> 2 km	196	155 (79.1)	41 (20.9)		
Modern house (X_9)					
Yes	241	215 (89.2)	26 (10.8)	0.103	0.748
No	745	659 (88.5)	86 (11.5)		
Source of drinking water (X_{10})					
Running tap water	480	431 (89.8)	49 (10.2)	1.230	0.267
Open source	506	443 (87.5)	63 (12.5)		
Access to TV(X_{11})					
Yes	338	317 (93.8)	21 (6.21)	13.526	< 0.001
No	648	557 (86.0)	91 (14.0)		
Malaria knowledge level (X_{12})					
High	204	194 (95.1)	10 (4.90)	14.201	< 0.001
Moderate	292	262 (89.7)	30 (10.3)		
Low	490	418 (85.3)	72 (14.7)		
Poor understanding of MTSB(X_{13})					
No	484	442 (91.3)	42 (8.68)	6.788	0.009
Yes	502	432 (86.1)	70 (13.9)		
The use of bed net (X_{14})					
Yes	839	759 (90.5)	80 (9.54)	18.592	< 0.001
No	147	115 (78.2)	32 (21.8)		
Travel history(X_{15})					
No	937	835 (89.1)	102 (10.9)	4.193	0.041
Yes	49	39 (79.6)	10 (20.4)		

3.4 Modeling malaria history among hilly communities in ENTP, Indonesia

The initial model of the logistic regression equation was built based on the variables showing a relationship with the malaria history, as indicated in Table 3. The estimation of each parameter in the logit function is presented in Eq. (8).

On the initial model (step one), the significance of each predictor was presented in Table 4.

$$\begin{aligned} Model\ 1 = & -4.016 - 0.533X_{2(1)} + 0.512X_{2(2)} \\ & - 0.354X_{2(3)} + 0.019X_{2(4)} \\ & - 0.009X_{3(1)} + 1.044X_{3(2)} \\ & + 0.567X_{4(1)} + 0.750X_{6(1)} \\ & - 0.440X_{7(1)} + 0.825X_{8(1)} \\ & + 0.580X_{11(1)} + 0.460X_{12(1)} \\ & + 0.773X_{12(2)} + 0.065X_{13(1)} \\ & + 0.065X_{14(1)} + 1.183X_{15(1)} \end{aligned} \quad (8)$$

Table 4. The significance of each predictor in the initial model

Stage	Predictors	B	S.E.	Wald	df	Sig.
Step 1[a]	Age group			5.603	4	0.231
	50 - 59	-0.533	0.376	2.006	1	0.157
	40 - 49	0.152	0.340	0.200	1	0.655
	30 -39	-0.354	0.355	0.998	1	0.318
	< 30	0.019	0.422	0.002	1	0.963
	Education of participants			17.430	2	0.000
	Primary school	-0.009	0.300	0.001	1	0.976
	No education	1.044	0.334	9.747	1	0.002
	outdoor occupation	0.567	0.272	4.360	1	0.037
	> 4 Family size	0.750	0.225	11.070	1	0.001
	< PMW HH Income	-0.440	0.526	0.701	1	0.403
	> 2 Km Distance to the nearest health service	0.825	0.241	11.742	1	0.001
	No access to TV	0.580	0.285	4.146	1	0.042
	Malaria knowledge level			4.483	2	0.106
	Moderate	0.460	0.398	1.337	1	0.248
	Low	0.773	0.386	4.013	1	0.045
	Poor understanding of MTSB	0.065	0.229	0.082	1	0.775
	No bed net use	0.664	0.256	6.720	1	0.010
	Having travel history in the last one month	1.183	0.408	8.389	1	0.004
	Constant	-4.016	0.629	40.813	1	0.000

Based on Table 4, there were some variables showing unsignificant effect partially to the malaria history including variable poor understanding of MTSB, age group, household income because p-value of these variables was greater than 5%. These variables were removed gradually from the model by applying the backward Wald method. In the final model, on step 4, the most significant variables were included in the model as indicated in Table 5.

Table 5. Summary of the goodness fit, simulant, and partial test on the final model

Predictors	B	S.E.	Wald	df	Sig.
Level of education			17.151	2	0.000
Level of education (1)	-0.035	0.284	0.015	1	0.902
Level of education (2)	0.961	0.309	9.692	1	0.002
Outdoor occupation	0.598	0.265	5.107	1	0.024
Family size > 4	0.728	0.218	11.154	1	0.001
Distance to the nearest health service > 2 km	0.825	0.236	12.256	1	0.000
No having access to TV	0.531	0.274	3.759	1	0.053
Malaria knowledge level			4.811	2	0.090
Malaria knowledge level (1)	0.470	0.392	1.440	1	0.230
Malaria knowledge level (2)	0.780	0.375	4.316	1	0.038
No use of bed net	0.694	0.253	7.515	1	0.006
Having travel history	1.231	0.403	9.319	1	0.002
Constant	-4.490	0.452	98.778	1	0.000
Omnibus Tests of Model Coefficients:					
Chi-square = 94.631		df = 10; Sig. = 0.000			
Hosmer and Lemeshow Test:					
Chi-square = 3.559	df = 8	Sig. = 0.895			

From Table 5, it was shown that the p-value of Omnibus Tests was less than 0.05, indicating that in the final model, there was a significant effect simultaneously of all predictors on malaria history. The goodness of fit of the model was evaluated by Hosmer and Lemeshow Test. It was evidence that the p-value of Hosmer and Lemeshow Test was greater than 0.05, signaling that the logistic model fitted the data well. The result of Wald test to evaluate the effect of each predictor on malaria history demonstrates that except for variable X_{11} (access to TV), all variables in Table 5 provided a significant effect on the malaria history of hilly communities in rural ENTP Indonesia. Therefore, the final model for malaria history of rural hilly communities in ENTP as indicated in Model 2.

Based on the Model 2, there are nine variables showing a significant effect on the malaria history for rural adults living in hilly areas in ENTP. The adjusted odds ratio value for each variable in multivariable analysis is calculated based on Eq. (7) to quantify the magnitude of the influence for each independent variable on the malaria history as stated in Table 6 below. From this table, it can be seen that the risk of malaria for hilly adults having no school is 2.6 times higher compared to those with at least junior high school education (adjusted odd ratio (AOR): 2.614, 95% confidence interval (CI): 1.428 – 4.787). The likelihood of malaria history for hilly adults having more than 4 family members is 2 times higher compared to those having small families' members (AOR: 2.071 with 95% CI: 1.351 – 3.174). The likelihood to have malaria history for hilly adults having low level of malaria knowledge was 2.2 times higher than those having a high level of malaria knowledge (AOR: 2.181 with 95% CI: 1.045 – 4.552). For hilly adults having no bed net, their likelihood of having malaria history was 2 times higher than those using bed net (AOR: 2.001 with 95% CI: 1.219 – 3.286). Finally, the risk of malaria history for those having no history of travel in the last month was 3.4 times higher than those having travel history (AOR: 3.423 with 95% CI: 1.553 – 7.543).

$$\begin{aligned} Model\ 2 = & -4.490 - 0.035X_{3(1)} + 0.961X_{3(2)} \\ & + 0.598X_{4(1)} + 0.728X_{6(1)} \\ & + 0.825X_{8(1)} + 0.470X_{12(1)} \\ & + 0.780X_{12(2)} + 0.694X_{14(1)} \\ & + 1.231X_{15(1)} \end{aligned} \tag{9}$$

Table 6. The influence of independent variables on the malaria history among hilly communities in rural ENTP, Indonesia

Predictors	Adjusted Odd Ratio and Its 95% Confidence Interval
Level of education (X_3)	
Junior high school or above	Reference
Primary school	0.966 (0.554, 1.683)
No education	2.614 (1.428, 4.787)
Main occupation (X_4)	
Indoor	Reference
Outdoor	1.818 (1.083, 3.054)
Family size (X_6)	
< = 4	Reference
> 4	2.071 (1.351, 3.174)
Distance to the nearest health service (X_8)	
< = 2 km	Reference
> 2 km	2.281 (1.438, 3.62)
Malaria knowledge level (X_{12})	
High	Reference
Moderate	1.6 (0.742, 3.449)
Low	2.181 (1.045, 4.552)
The use of bed net (X_{14})	
Yes	Reference
No	2.001 (1.219, 3.286)
Travel history (X_{15})	
Yes	Reference
No	3.423 (1.553, 7.543)

4. DISCUSSIONS

This research is the first study to investigate the effect of malaria knowledge level on the risk factors of malaria history in rural communities living in hilly areas of ENTP, Indonesia. The findings of this study could be used as the baseline data to investigate the disparity of malaria risk factors among different geographical settings, including in the highland and coastline areas. The results of this study show that the prevalence of malaria history is still high, and the behavioral aspects of malaria, including the level of malaria knowledge and use of mosquito nets, are significantly associated with malaria cases in this region. Moreover, from the demographic aspects, it was found that a low level of education and a greater family size were the important malaria risk factors for hilly communities. For this reason, malaria health interventions in order to increase malaria knowledge in local communities, focused on rural communities with low education and larger family sizes, are very critical to support the achievement of malaria elimination before 2030.

The findings of this study indicated that the prevalence of malaria history was still high (11.4%). Our result is in line with the current study in ENTP applying medical records of malaria patients in local health centers in this province, showing that the prevalence of malaria history in this region is still high, ranging from 6.08% [6] to 15.5% [7]. These findings indicated that malaria is still the main health issue in this province and needs collaborative effort from all authorities in the region to support the national commitment of the Indonesian Government to achieve malaria elimination by 2030 [3].

In this study, we found that there was a significant relationship between the level of education and the history of malaria for hilly communities. The research results show that adults in hilly areas having no level of education have the highest risk of malaria history, while it was the lowest in the group with junior high school education or above. This finding was verified with other studies in Indonesia [21, 52, 53] and other studies internationally [42, 54-56] showing the role of high levels of education in reducing malaria cases. This might be because people with a high level of education have the skills to understand the written concepts of information [57] and have many opportunities to be exposed to various sources of information [58]. As a result, this community group could recognize the symptoms of disease and how to prevent disease [10] which ultimately could decrease the malaria transmission [54]. This highlights the strength of education to support malaria elimination in this region. Furthermore, this study also indicated that more than 50% of the hilly community have a low level of education or have no experience in school. This result corroborated with the previous study revealing the rate of drop out of school was high in rural ENTP [59, 60]. This situation would provide more challenges to the effort to reduce malaria cases in this area. Considering these situations, intervention to reduce malaria transmission might accomplish well by delivering a health education promotion with speaker announcement [61] and music [62] as revealed in other countries.

The findings of this study also suggest a significant association between outdoor occupations and malaria history among rural communities in hilly regions. Adults engaged in outdoor work were found to be nearly twice as likely to have a history of malaria compared to those with indoor occupations. This result is consistent with previous studies [40, 43, 63], which reported higher malaria prevalence among individuals with outdoor jobs. This association may be attributed to increased exposure to Anopheles mosquito bites, which are common in the study area [64]. Furthermore, as the primary livelihood in this province involves agricultural work [65], individuals are more frequently outdoors, increasing their risk of mosquito bites. Raising awareness among this occupational group about protective measures while working outdoors is critical to advancing malaria elimination efforts in ENTP, Indonesia.

Additionally, the study revealed a significant relationship between household size and malaria history. The risk of malaria was found to be twice as high in households with five or more members compared to those with smaller family sizes. This finding is in line with previous research conducted in other settings [41, 66, 67], which identified a positive correlation between household size and malaria risk. Larger households may attract more mosquitoes due to stronger collective odor cues, thereby increasing the likelihood of malaria transmission [68].

Our research further shows that the level of knowledge about malaria is a significant factor related to the malaria history in the hilly communities in this province. The likelihood of malaria in hilly adults with low levels of malaria knowledge is double as high as those with high levels of malaria knowledge. These findings are consistent with other studies showing that low levels of knowledge about malaria increase the likelihood of contracting malaria [40, 69-71]. This could be understood as people having low levels of malaria knowledge do not understand how to recognize the symptoms of the disease and to seek appropriate treatment during their sickness. In addition, other studies show that the variation in knowledge of malaria preventive measures among different malaria endemic settings exists in this study area and knowledge about long-lasting insecticide-treated bed nets (LLIN) is only common in high endemic areas in this province [48], and the practice of using various types of malaria prevention measures is low in the province [52]. These situations may pose a greater challenge to efforts to reduce malaria prevalence in this region. Increasing knowledge about malaria prevention measures in all malaria endemic settings in this province could enrich the opportunities to practice various types of malaria prevention measures, thereby reducing malaria prevalence [72] and increasing malaria elimination [73].

Moreover, this study also depicted that there was a significant effect of sleeping on the bed net during sleeping time on the malaria history. This study reveals that the likelihood to have malaria history for those sleeping without bed nets was two times higher than their counterpart. Our finding corroborates with other studies indicating that there is a negative association between the use of bed nets and risk of malaria [35, 42, 74]. The use of bed nets, particularly LLINS has provided a significant impact on the decline of malaria globally since 2000 and has been recommended as the best malaria prevention measures [75]. Currently, the Indonesian government utilized LLINs as the major vector control strategy in the eastern part of the country particularly in high MESs including in ENTP [3]. The distribution of this treated net should be followed by a health education session to encourage rural communities in using this kind of bed net. Failure to educate people on the importance of treated nets to reduce the risk of malaria leads to the mis use of bed nets for instance to protect their food materials as indicated in other studies [76].

This study emphasizes some predictors for malaria history for hilly communities in rural ENTP including the education level and malaria knowledge level of participants. Thus, it is recommended that to boost malaria elimination achievement in this region, the partnership among sectors is crucial. This includes collaborative efforts between the health and education department in the development of a malaria intervention package to enhance malaria knowledge of hilly communities. Malaria knowledge modules should be part of the local school curriculum to enhance malaria knowledge of residents. The great accomplishment of the Chinese government to obtain malaria elimination status in 2021 due to the huge effort to advance malaria knowledge of student's community [77, 78].

This study supplies the first reliable data on the malaria prevalence of rural communities living in hilly land applying large sample sizes. Despite this advantage, the potential limitation of this study was the fact that malaria prevalence calculation was based on the malaria history in the last two years reported by participants that might be susceptible to recall bias. Moreover, due to the nature of the cross-sectional study, the causality inference could not be done by this study. However, our findings are still in line with the current study on malaria prevalence based on the medical record analysis in rural ENTP showing that even though the trend of malaria declined in the last ten year, the prevalence was still high in this study area and need collaborative effort amongst sector to address the complexity of malaria in this region [6, 7].

5. CONCLUSIONS

The prevalence of malaria is still high among hilly communities in rural East Nusa Tenggara Province, Indonesia. This research showed that the low level of education, large family members, low level of malaria knowledge, sleeping without a mosquito net, outdoor occupation are very important risk factors for malaria in this study area. Collaborative effort of many sectors is critical, particularly between the health and education department to design and implement malaria health interventions to boost malaria knowledge of hilly communities. The intervention should be prioritized for those having low education, farmers, having large family sizes. Future research will explore the variation of malaria risk factors among different topographies by applying confirmed malaria cases reported by professional health centers in order to capture the disparity of malaria likelihood among diverse geographical settings. Identifying the location of the high-risk group of malaria is critical to assist public health experts in designing and targeting malaria interventions tailored to local conditions to support global effort for malaria elimination zone by 2030.

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