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# Determinants of Appropriate Malaria Treatment-Seeking in Rural East Nusa Tenggara, Indonesia: A Multilevel Logistic Regression Analysis

Robertus Dole Guntur[1*], Maria Lobo[1], Brian Juned Septory[1], Irvandi Gorby Pasangka[1], Helga J. Ndun[2], Damai Kusumaningrum[3], Yulianti Paula Bria[4], Stanis Man[5], Ganesha Lapenangga Putra[1,6]

[1] Mathematics Study Program, Nusa Cendana University, Kupang 85001, Indonesia
[2] Public Health Department, Nusa Cendana University, Kupang 85001, Indonesia
[3] Animal Health Study Program, State Agricultural Polytechnic, Kupang 85111, Indonesia
[4] Computer Science Department, Widya Mandira Catholic University, Kupang 85361, Indonesia
[5] Graduate Program in Management, Widya Mandira Catholic University, Kupang 85361, Indonesia
[6] School of Mathematics and Statistics, The University of Melbourne, Parkville, VIC 31010, Australia

Corresponding Author Email: robertus_guntur@staf.undana.ac.id



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**ABSTRACT**

To achieve malaria elimination, ensuring prompt and appropriate treatment-seeking behavior is essential. While determinants of treatment-seeking vary across endemic settings, the specific influence of community-level factors in rural East Nusa Tenggara (NTT), Indonesia, has not been adequately examined. This study examined the determinants of self-reported appropriate malaria treatment-seeking behavior using a two-level logistic regression model to account for individual and village-level heterogeneity. The analysis included 894 individuals nested within 25 villages and incorporated six individual-level and three village-level predictors. The analysis revealed statistically significant determinants at both levels. At the individual level, attaining at least a high school education was a strong predictor of appropriate treatment-seeking (adjusted odds ratio (AOR) = 1.84; 95% confidence interval (CI): 1.03–3.26). At the community level, the presence of a health centre (AOR = 7.24; 95% CI: 1.14–45.99) and good village accessibility (AOR = 4.37; 95% CI: 2.18–8.78) significantly increased the likelihood of seeking appropriate care. The presence of significant contextual effects underscores the importance of accounting for hierarchical data structures. These findings suggest that malaria control strategies in NTT should extend beyond health education. Interventions should integrate individual educational efforts with structural improvements, particularly in relation to health service availability and transportation accessibility, to effectively enhance treatment-seeking behavior in high-endemic areas.

## 1. INTRODUCTION

Malaria is an infectious disease present in 83 countries worldwide, with an estimated 3.5 billion people at risk of contracting malaria and 263 million people suffering from the disease by 2023 [1, 2]. In Southeast Asia, approximately 4.1 million people suffered from malaria during this period, with India accounting for 51% of cases, while Indonesia contributed 27% [1].

Indonesia has a national commitment to eliminating malaria by 2030 [3]. As a result of this commitment, about three-quarters of the districts in the state received malaria-free certificate in 2023 [4]. However, this achievement reveals a significant disparity between the western and eastern parts of the country. Most of the districts in the western part have been classified as malaria free area, whilst most of the districts in the eastern part, including in East Nusa Tenggara (NTT), are still categorized as high, moderate, and low endemic settings [4]. The current data shows that in NTT, the total number of malaria cases was 6931, with the majority of the cases contributed by Sumba Island [5]. Most districts on this island were still grouped as high malaria endemic settings, and most of the cases were generally caused by Plasmodium falciparum [6]. However, the prevalence of Plasmodium vivax is relatively high, ranging from 6.39% [6] to 23.3% [7]. This situation provides a challenge for achieving malaria elimination in this province, as the complete treatment for malaria vivax requires a high awareness of people to finish the treatment for 14 days [8, 9].

In order to achieve malaria elimination, active community participation is needed in identifying malaria symptoms and seeking appropriate treatment [10]. The World Health Organization (WHO) recommends that appropriate malaria treatment should be initiated within 24 hours of the onset of symptoms and administered in a professional health facility [11]. Furthermore, the WHO suggested malaria treatment using Artemisinin-based combination therapies (ACTs) as the ideal approach to support the achievement of malaria elimination [11, 12]. The application of this strategy has had a positive effect in reducing the number of malaria cases globally. Literature showed that the policy using ACTs had reduced the mortality rate of children who were under five years old by 72% in Zanzibar, Africa region [13] and malaria reduction cases by 32.8% in Vietnam [14]. However, the effectiveness of ACTs use is highly dependent on community behavior to seek a malaria treatment. The proportion of people in the Southeast Asian region who request malaria treatment in government health services, where a complete package for malaria diagnosis and treatment is available, is only 27.62% [15]. Increasing public awareness in seeking correct malaria treatment is crucial to reduce severe malaria [16]; hospitalizations in clinics [17], and malaria transmission at the community level [18].

Treatment-seeking behavior was a complex outcome shaped by interactions between individual characteristics and contextual environments. Previous studies had identified factors such as gender [19], age group [20], education [21-24], socioeconomic status [23], knowledge of malaria symptoms [20], and perceived severity [24] as important individual-level determinants. However, growing evidence suggests that these individual factors operate within broader structural and community contexts, including health service availability, transportation infrastructure, and geographic accessibility [8-10]. Ignoring these contextual influences can lead to incomplete inference and biased estimates, particularly in rural and high-endemic settings where access to care is unevenly distributed.

Analyzing treatment-seeking behavior presents a specific mathematical challenge due to the hierarchical structure of the data. In rural settings, individuals are not independent entities but are nested within specific clusters (villages or communities). Standard statistical models, such as single-level logistic regression, operate under the assumption of independence of observations. Applying such models to nested data violates this assumption, ignoring the intraclass correlation coefficient (ICC) and leading to underestimated standard errors and inflated Type I errors [25, 26]. To accurately model the probability of appropriate treatment-seeking, it is necessary to employ a multilevel modeling approach. This mathematical framework allows for the simultaneous estimation of variance at the individual level (micro-system) and the community level (macro-system), providing a more robust quantification of contextual effects [27, 28]. While several studies have examined malaria treatment-seeking behavior in Indonesia [23, 29-31], most of these studies have focused on individual-level determinants or employed single-level analytical approaches. Consequently, the role of village-level contextual factors in shaping appropriate treatment-seeking behavior in rural NTT has not been sufficiently quantified using rigorous hierarchical modeling techniques.

In response to this gap, the present study applies a two-level multilevel logistic regression model to investigate determinants of appropriate malaria treatment-seeking behavior among individuals nested within villages in rural NTT. By integrating individual- and community-level predictors within a unified modeling framework, this study aims to (i) quantify the relative contribution of contextual effects; (ii) assess the impact of structural factors such as health facility presence and village accessibility; and (iii) demonstrate the value of multilevel modeling for health behavior analysis in endemic settings.

To systematically analyze these determinants, this study utilizes Andersen's behavioral model of health services use [32] as a conceptual framework. Andersen's model posits that health service utilization is a function of three dynamics: (1) Predisposing factors (sociodemographic characteristics and beliefs that exist before illness, such as education and malaria knowledge); (2) Enabling factors (the logistical and community resources that facilitate access to care, such as village road accessibility and the physical presence of health centres); and (3) Needing factors (the perceived or evaluated health status). By applying this framework within a multilevel modeling architecture, we aimed to disentangle how individual predisposing traits interact with community-level enabling structures to drive treatment-seeking behavior.

The findings from this mathematical model are intended to guide the optimization of malaria control strategies, shifting the focus from purely educational interventions to a holistic approach that integrates structural engineering improvements in rural infrastructure. It is also to provide a methodological contribution relevant to applied mathematical modeling in public health systems.

## 2. MATERIALS AND METHODS

### 2.1 Data source

The analysis utilized secondary data obtained from a previously published community-based intervention aiming to enhance malaria knowledge among rural residents in NTT, Indonesia [33]. In that study, data were collected from four sub-districts representing a high malaria-endemic setting in the region. All 25 villages within these areas participated, with 30-40 household heads randomly sampled in proportion to village size, resulting in a total of 894 respondents. In each selected village, a systematic random sampling technique was employed. The sampling frame was constructed using the official village household registry (Data Penduduk / Kartu Keluarga) provided by the Village Head. From this list, 30 to 40 households were selected per village to ensure sufficient statistical power for the multilevel analysis while adhering to logistical constraints standard in cluster surveys. Data was collected by interviewing participants who were at least 18 years old, using a validated questionnaire. The study followed the principles of the Declaration of Helsinki, and ethical clearance was granted by the Human Ethics Committee of Nusa Cendana University (Approval No. 42/UN15.21/KEPK/2024).

### 2.2 Research variables

Three binary outcome variables were assessed:

(1) awareness of seeking malaria treatment within 24 hours of symptom onset $(y_1)$, (2) awareness of obtaining care at professional health facilities $(y_2)$, and (3) comprehensive understanding of reported appropriate malaria treatment-seeking $(y_3)$, defined as seeking treatment within 24 hours and at a professional facility. Each of these variables was a categorical variable with one for yes and zero for no. Moreover, nine explanatory variables consisting of six variables at the individual level and three variables at the community level. At individual level, it contained gender $(X_1)$, age category $(X_2)$, level of education $(X_3)$, income group $(X_4)$, awareness for preventing malaria $(X_5)$, hearing

malaria term ($X_6$). At community level, it consisted of health centre availability ($X_7$), geographical condition ($X_8$), access to village ($X_9$). $X_1$ was grouped as female and male; $X_2$ was categorized as < 60 and ≥ 60. $X_3$ had three categories, including no education at all, primary school, and at least junior high school level. For $X_4$, it was classified as greater than minimum wage province (MWP) and less than MWP. Whilst each variable of $X_5, X_6$, and $X_7$ had two categories, no and yes. To ensure sufficient statistical power and model convergence, the geographic topography variable ($X_8$), originally categorized as coastal, hilly, and rice fields, was recoded into a binary variable: Highland (comprising hilly and mountainous terrain) and Lowland (comprising coastal and flat plains). This binary classification better captures the distinct topographical barriers present in the East Nusa Tenggara archipelago. Then, for $X_9$, it had easy access and difficult access between and within the village. Prior study shown that being a female [19], young age, and no education [34], living in lowland and far from health facilities decreased the probability to have good understanding of malaria treatment-seeking behavior [20, 23, 31, 34]. Therefore, on the univariate and multivariable analysis, these categories became a reference category.

### 2.3 Modelling stage

The analysis began with descriptive statistics to determine the prevalence of each outcome variable. To verify independence among predictors, a multicollinearity test was conducted through tolerance (TOL) and variance inflation factor (VIF) values. These values were defined as follows [35]:

$$TOL_i = 1 - R_i^2, for\ i = 1, 2, \ldots, 9 \quad (1)$$

where, $R_i^2$ denoted determination coefficient accomplished by regressing $X_i$ on all the other independent variables $X_1, X_2, \ldots, X_{12}$ (excluding $X_i$) and

$$VIF_i = \frac{1}{Tolerance_i} = \frac{1}{1 - R_i^2} \quad \text{for } i = 1, 2, \ldots, 9 \quad (2)$$

When TOL value ≤ 0.1 and VIFs >10, it was a strong indication of multicollinearity among independent variables [35]. Furthermore, analysis was continued by exploring the relationship between each dependent variable ($y_1, y_2$, and $y_3$) and all predictors with chi-square ($\chi^2$) test following the hypothesis:

$H_o$: $X_i$ was not associated with $y_1$, versus $H_1$: $X_i$ was associated with $y_1$;

$H_o$: $X_i$ was not associated with $y_2$, versus $H_1$: $X_i$ was associated with $y_2$;

$H_o$: $X_i$ was not associated with $y_3$, versus $H_1$: $X_i$ was associated with $y_3$, for $i$ = 1, 2, ..., 9.

The rejection of the null hypothesis could be done when $\chi^2_{count} > \chi^2_{table}$ or p ≤ 0.05. In this case, $\chi^2_{count}$ was computed by

$$\chi^2_{count} = \sum_{i=1}^{r} \sum_{j=1}^{c} \frac{\left(O_{ij} - E_{ij}\right)^2}{E_{ij}} \quad (3)$$

where, $r$ represented the number of rows and $c$ denoted the quantity of columns in a table contingency during tabulation between the dependent variable and each independent variable. The computation of Eq. (3) was conducted separately for $y_1, y_2$, and $y_3$.

### 2.4 Modeling with multilevel logistic regression for $y_1$

Variable selection for the multivariate model followed a purposeful selection algorithm [36]. Initially, bivariate analysis was performed to screen for potential predictors, using a liberal threshold of p < 0.25 to capture all potentially relevant variables. However, the final inclusion of variables in the multilevel logistic regression was not based solely on statistical significance. Variables of known theoretical importance—such as gender, age group, education level, and income group—were retained in the final model to control for confounding and ensure content validity, regardless of their individual statistical significance in the bivariate stage. This approach ensures that the model reflects the complex, hierarchical nature of treatment-seeking behavior rather than relying on automated stepwise elimination.

All independent variables showing a significant relationship with $y_1$ theoretically and statistically as shown in the chi-square test of bivariate analysis, were incorporated in the multilevel analysis for $y_1$. A two-level multilevel logistic regression model was employed because the outcome variable, for $y_1$ was binary (one for yes and zero for no) and the data had a hierarchical structure, with individuals nested within villages. This model accounts for within-village correlation and captures heterogeneity across villages. The analysis included 894 individuals (level 1) from 25 villages (level 2). The predictors consisted of six individual-level variables and three village-level variables. Therefore, the multilevel logistic regression model with a village-level random intercept was specified as:

$$\ln\left(\frac{p_{ij}}{1 - p_{ij}}\right) = \beta_0 + \sum_{k=1}^{6} \beta_k X_{kij} + \sum_{l=1}^{3} \gamma_l Z_{lj} + u_{0j} \quad (4)$$

where, $p_{ij}$ was the probability that individual $i$ in village $j$ sought malaria treatment, $X_{kij}$ and $Z_{lj}$ denoted individual and village-level predictors, respectively; $\beta_k$ and $\gamma_l$ was fixed-effect coefficients, and $u_{0j}$ was the village-specific random effect, assumed to follow a normal distribution with mean zero and variance $\sigma_u^2$. Model estimation was performed using the generalized linear mixed modeling framework with a logit link function and binomial error distribution. Parameters were estimated via maximum likelihood using the Laplace approximation as implemented in the GENLINMIXED procedure in Statistical Package for the Social Sciences (IBM Corp.). This model estimation proceeded in three steps. Firstly, an intercept-only model, yielding Model I, was fitted to assess between-village variation and to compute the ICC. The ICC was determined as follows [37, 38]:

$$ICC = \frac{\sigma_u^2}{\sigma_u^2 + 3.29} \quad (5)$$

Secondly, individual-level predictors, yielding Model II, were added to evaluate their associations with treatment-seeking behavior. Finally, individual and village-level predictors, Model III, were incorporated to assess contextual effects after adjustment for individual characteristics. For statistical inference, the results were reported as odds ratios (ORs) with 95% confidence interval (CI) to quantify the significant impact of each predictor on $y_1$ with formula:

$$OR = exp\left(\hat{\beta}_k\right), \text{for } k = 1,2,\dots,9 \quad (6)$$

And the computation of 95% interval estimate of OR was determined by

$$Exp\left[\hat{\beta}_k \pm 1.96 * SE(\hat{\beta}_k)\right], \text{for } k = 1,2,\dots,9 \quad (7)$$

The variance of the random intercept, the proportional change in variance (PCV), median odds ratio (MOR), and ICC were used to quantify between-village heterogeneity [26, 28]. Statistical significance was defined as $p < 0.05$. Model performance was evaluated using the Receiver Operating Characteristic (ROC) curve and the Area Under the Curve (AUC). To ensure model parsimony, two-way interactions between key individual and community-level variables (e.g., Education x Village Access) were explored but were excluded from the final model as they did not reach statistical significance ($p > 0.05$) or improve the Akaike Information Criterion (AIC). Finally, modeling with multilevel logistic regression, for $y_2$, and $y_3$ was conducted with the same procedure as shown for $y_1$.

## 3. RESULTS

### 3.1 Awareness of seeking malaria treatment among the rural community in high malaria endemic settings of East Nusa Tenggara

Table 1 summarizes respondents' awareness regarding when and where to obtain malaria treatment. Nearly all participants (96.6%; with 95% CI: 95.4–97.8) stated they would seek care if they or a family member developed malaria symptoms. However, only 47.1%, 95% CI: 42.3–51.9, reported doing so within 24 hours. 34%, with 95% CI: 28.7–39.3, of them sought the treatment after 48 hours. Most respondents (84.8%; with 95% CI: 82.2–87.3) preferred government-run facilities. Overall, the prevalence of awareness to request the treatment in professional health services was 85.9%, with 95% CI: 83.4–88.4, and the prevalence of good understanding of malaria treatment-seeking was 45.3% with 95% CI: 40.5–50.2, as indicated in Table 1.

**Table 1.** Awareness on when and where to find the malaria medication among the countryside community in high-endemic settings

| Variables | Number | % | 95% Confidence Interval |
|---|---|---|---|
| Seeking medication if participants or their family members suffer from malaria | | | |
| Yes | 864 | 96.6 | [95.4, 97.8] |
| No | 30 | 3.36 | [0.00, 9.80] |
| How fast can participants or their family members seek medication if they suffer from malaria | | | |
| One day | 421 | 47.1 | [42.3, 51.9] |
| Two days | 304 | 34.0 | [28.7, 39.3] |
| Three days | 97 | 10.9 | [4.66, 17.0] |
| At least four days | 42 | 4.70 | [0.00, 11.1] |
| did not go for medication | 30 | 3.36 | [0.00, 9.80] |
| Place to seek the medication | | | |
| Government health services | 758 | 84.8 | [82.2, 87.3] |
| Private health facilities | 10 | 1.12 | [0.00, 7.64] |
| Drug store | 48 | 5.37 | [0.00, 11.7] |
| Traditional treatment | 27 | 3.02 | [0.00, 9.48] |
| Self-medication | 5 | 0.56 | [0.00, 7.10] |
| Others | 16 | 1.79 | [0.00, 8.29] |
| Not applicable | 30 | 3.36 | [0.00, 9.80] |
| Awareness to find medication within 24 hours | 421 | 47.1 | [42.3, 51.9] |
| Awareness to find medication at professional health services | 768 | 85.9 | [83.4, 88.4] |
| Good understanding of malaria treatment-seeking behavior | 405 | 45.3 | [40.5, 50.2] |

**Table 2.** The value of tolerance and variance inflation factor (VIF) for assessments of high collinearity amongst nine predictors

| Variables | Tolerance | VIF |
|---|---|---|
| $X_1$ | 0.983 | 1.017 |
| $X_2$ | 0.907 | 1.102 |
| $X_3$ | 0.841 | 1.189 |
| $X_4$ | 0.953 | 1.049 |
| $X_5$ | 0.430 | 2.324 |
| $X_6$ | 0.412 | 2.426 |
| $X_7$ | 0.760 | 1.316 |
| $X_8$ | 0.877 | 1.141 |
| $X_9$ | 0.694 | 1.441 |

### 3.2 Multicollinearity test

One of the requirements for doing modeling with multilevel logistic regression is the absence of high correlation among predictors in a model. Therefore, the existence of multicollinearity was assessed by computing the TOL value and VIFs as indicated in Eqs. (1)-(2), respectively. The result of the computation is exhibited in Table 2. $Toelrance_i > 0.1$ and $VIF_i < 10$, for $i = 1,2,\dots,9$. This result implies that there is no multicollinearity among predictors in this analysis.

### 3.3 Chi-square test

The initial connection between all predictors and each of,

$y_1, y_2$, and $y_3$, was explored by the chi-square test. The computation of the chi-square value was shown in Eq. (3), and the results of the computation are presented in Tables 3-5. In Table 3, it shows bivariate associations between predictors and outcome, $y_1$. Gender ($\chi^2 = 0.532$; $p = 0.466$) and age group ($\chi^2 = 0.133$; $p = 0.715$) were not significant. Education was significant ($\chi^2 = 16.47$; $p < 0.001$), with participants completing at least high school more likely to seek timely treatment (55.9%) than those with primary (43.3%) or no formal education (39.1%). Higher income (> MWP) was associated with prompt treatment (79.3% vs. 46%; $\chi^2 = 12.49$; $p < 0.001$), as was awareness that malaria can be prevented ($\chi^2 = 46.58$; $p < 0.001$) and prior exposure to malaria-related information ($\chi^2 = 34.56$; $p < 0.001$). At the community level, health centre availability ($\chi^2 = 89.16$; $p < 0.001$) and easy village access ($\chi^2 = 66.16$; $p < 0.001$) increased timely treatment. Geography was not significant. These results highlighted the importance of both educational and infrastructural factors in facilitating prompt malaria treatment.

**Table 3.** The chi-square test value for the association with $y_1$ and predictors

| Variables | | Seeking Malaria Treatment Within 24 Hours | | Chi-Square Test Value | P-Value |
|---|---|---|---|---|---|
| | | No, n (%) | Yes, n (%) | | |
| Total | 894 | | | | |
| Individual level | | | | | |
| Gender | | | | | |
| Male | 445 | 230 (51.7) | 215 (48.3) | | |
| Female | 449 | 243 (54.1) | 206 (45.9) | 0.532 | 0.466 |
| Age group | | | | | |
| > = 60 | 178 | 92 (51.7) | 86 (48.3) | | |
| < 60 | 716 | 381 (53.2) | 335 (46.8) | 0.133 | 0.715 |
| Education level | | | | | |
| At least high school | 322 | 142 (44.1) | 180 (55.9) | | |
| Primary | 416 | 236 (56.7) | 180 (43.3) | | |
| Never school | 156 | 95 (60.9) | 61 (39.1) | 16.47 | < 0.001 |
| Income | | | | | |
| > MWP | 29 | 6 (20.7) | 23 (79.3) | | |
| < MWP | 865 | 467 (54) | 398 (46) | 12.49 | < 0.001 |
| Awareness that malaria could be prevented | | | | | |
| Yes | 797 | 390 (48.9) | 407 (51.1) | | |
| No | 97 | 83 (85.6) | 14 (14.4) | 46.58 | < 0.001 |
| Hearing the malaria term | | | | | |
| No | 59 | 53 (89.8) | 6 (10.2) | | |
| Yes | 835 | 420 (50.3) | 415 (49.7) | 34.56 | < 0.001 |
| Community level | | | | | |
| Health centre availability | | | | | |
| Yes | 143 | 24 (16.8) | 119 (83.2) | | |
| No | 751 | 449 (59.8) | 302 (40.2) | 89.16 | < 0.001 |
| Geography condition | | | | | |
| Highland | 627 | 326 (52) | 301 (48) | | |
| Lowland | 267 | 147 (55.1) | 120 (44.9) | 0.705 | 0.401 |
| Access to the village | | | | | |
| Easy | 295 | 99 (33.6) | 196 (66.4) | | |
| Difficult | 599 | 374 (62.4) | 225 (37.6) | 66.16 | < 0.001 |

Note: MWP: minimum wage province.

**Table 4.** The chi-square test value for the association with $y_2$ and predictors

| Variables | | Malaria Seeking Treatment at Professional Health Facilities | | Chi-Square Test Value | P-Value |
|---|---|---|---|---|---|
| | | No, n (%) | Yes, n (%) | | |
| Total | 894 | | | | |
| Individual level | | | | | |
| Gender | | | | | |
| Male | 445 | 74 (16.6) | 371 (83.4) | | |
| Female | 449 | 52 (11.6) | 397 (88.4) | 4.704 | 0.03 |
| Age group | | | | | |
| > = 60 | 178 | 27 (15.2) | 151 (84.8) | | |
| < 60 | 716 | 99 (13.8) | 617 (86.2) | 0.212 | 0.645 |
| Education level | | | | | |
| At least high school | 322 | 27 (8.4) | 295 (91.6) | | |
| Primary | 416 | 68 (16.3) | 348 (83.7) | | |
| Never school | 156 | 31 (19.9) | 125 (80.1) | 14.71 | < 0.001 |
| Income | | | | | |
| > MWP | 29 | 1 (3.40) | 28 (96.6) | | |
| < MWP | 865 | 125 (14.5) | 740 (85.5) | 2.81 | 0.094 |
| Awareness that malaria could be prevented | | | | | |
| Yes | 797 | 101 (12.7) | 696 (87.3) | | |

| | | | | | |
|---|---|---|---|---|---|
| No | 97 | 25 (25.8) | 72 (74.2) | 12.26 | < 0.001 |
| Hearing the malaria term | | | | | |
| No | 59 | 20 (33.9) | 39 (66.1) | | |
| Yes | 835 | 106 (12.7) | 729 (87.3) | 20.46 | < 0.001 |
| Community level | | | | | |
| Health centre availability | | | | | |
| Yes | 143 | 3 (2.1) | 140 (97.9) | | |
| No | 751 | 123 (16.4) | 628 (83.6) | 20.23 | < 0.001 |
| Geography condition | | | | | |
| Highland | 627 | 81 (12.9) | 546 (87.1) | | |
| Lowland | 267 | 45 (16.9) | 222 (83.1) | 2.39 | 0.122 |
| Access to the village | | | | | |
| Easy | 295 | 31 (10.5) | 264 (89.5) | | |
| Difficult | 599 | 95 (15.9) | 504 (84.1) | 4.675 | 0.031 |

**Table 5.** The chi-square test value for the association with $y_3$ and predictors

| Variables | | Reported Appropriate Malaria Treatment-Seeking Behaviour | | Chi-Square Test Value | P-Value |
|---|---|---|---|---|---|
| | | No, n (%) | Yes, n (%) | | |
| Total | 894 | | | | |
| Individual level | | | | | |
| Gender | | | | | |
| Male | 445 | 240 (53.9) | 205 (46.1) | | |
| Female | 449 | 249 (55.5) | 200 (44.5) | 0.209 | 0.647 |
| Age Group | | | | | |
| > = 60 | 178 | 94 (52.8) | 84 (47.2) | | |
| < 60 | 716 | 395 (55.2) | 321 (44.8) | 0.32 | 0.572 |
| Education level | | | | | |
| At least high school | 322 | 146 (45.3) | 176 (54.7) | | |
| Primary | 416 | 244 (58.7) | 172 (41.3) | | |
| Never school | 156 | 99 (63.5) | 57 (36.5) | 18.84 | < 0.001 |
| Income | | | | | |
| > MWP | 29 | 6 (20.7) | 23 (79.3) | | |
| < MWP | 865 | 483 (55.8) | 382 (44.2) | 13.99 | < 0.001 |
| Awareness that malaria could be prevented | | | | | |
| Yes | 797 | 406 (50.9) | 391 (49.1) | | |
| No | 97 | 83 (85.6) | 14 (14.4) | 41.84 | < 0.001 |
| Hearing the malaria term | | | | | |
| No | 59 | 53 (89.8) | 6 (10.2) | | |
| Yes | 835 | 436 (52.2) | 399 (47.8) | 31.47 | < 0.001 |
| Community level | | | | | |
| Health centre availability | | | | | |
| Yes | 143 | 24 (16.8) | 119 (83.2) | | |
| No | 751 | 465 (61.9) | 286 (38.1) | 98.75 | < 0.001 |
| Geography condition | | | | | |
| Highland | 627 | 341 (54.4) | 286 (45.6) | | |
| Lowland | 267 | 148 (55.4) | 119 (44.6) | 0.082 | 0.774 |
| Access to the village | | | | | |
| Easy | 295 | 100 (33.9) | 195 (66.1) | | |
| Difficult | 599 | 389 (64.9) | 210 (35.1) | 76.87 | < 0.001 |

Bivariate analysis (Table 4) reveals significant associations between both individual- and community-level factors and outcome, $y_2$. Females were more likely than males to seek professional care (88.4% vs. 83.4%; $\chi^2$ = 4.704, p = 0.03). Educational attainment was strongly associated with treatment seeking ($\chi^2$ = 14.71, p < 0.001), with participants having at least a high school education showing the highest utilization (91.6%). Awareness of malaria prevention ($\chi^2$ = 12.26, p < 0.001) and prior exposure to malaria-related information ($\chi^2$ = 20.46, p < 0.001) were also positively associated. At the community level, health centre availability ($\chi^2$ = 20.23, p < 0.001) and easy village access ($\chi^2$ = 4.675, p = 0.031) increased professional care utilization. Age, income, and geographic condition were not significant.

Table 5 shows bivariate associations between predictors and outcome, $y_3$. Gender ($\chi^2$ = 0.209; p = 0.647) and age group ($\chi^2$ = 0.32; p = 0.572) were not significant. Education was strongly associated ($\chi^2$ = 18.84; p < 0.001), with participants completing at least high school more likely to seek appropriate treatment (54.7%) than those with primary (41.3%) or no formal education (36.5%). Higher income (> MWP) increased appropriate treatment-seeking (79.3% vs. 44.2%; $\chi^2$ = 13.99; p < 0.001), as did awareness of malaria prevention ($\chi^2$ = 41.84; p < 0.001) and prior exposure to malaria-related information ($\chi^2$ = 31.47; p < 0.001). At the community level, health centre availability ($\chi^2$ = 98.75; p < 0.001) and easy village access ($\chi^2$ = 76.87; p < 0.001) were positively associated, while geography was not significant.

### 3.4 A two-level multilevel logistic regression model for $y_1$

Table 6 summarizes the multilevel logistic regression results for determinants of seeking malaria treatment within 24 hours. The null model demonstrated substantial village-level clustering, with a community-level variance of 3.211 and an ICC of 49.39%. In Model II, inclusion of individual-level predictors modestly reduced village-level variance (PCV = 6.57%). Educational attainment was the only significant individual-level factor, with individuals having at least a high school education showing higher odds of timely treatment seeking compared to those with no formal education (adjusted odds ratio (AOR) = 1.85; 95% confidence interval (CI): 1.06–3.24). In the full model (Model III), these effects remained significant, and village-level variance further decreased (PCV = 26.28%; ICC = 41.84%). The median odds ratio declined from 5.53 to 4.34, indicating reduced but persistent village-level heterogeneity. Although Model III reduced unexplained village-level variance, its higher AIC and BIC values indicate reduced parsimony relative to simpler models, reflecting the trade-off between model complexity and goodness of fit.

**Table 6.** Multilevel analysis for determinant factors associated with $y_1$ and predictors

| Variable | Model I (Null Model) | Model II (Individual Level) | Model III (Mixed Model) |
|---|---|---|---|
| Individual level | | | |
| Gender | | | |
| Male | | 1.19 (0.85, 1.66) | 1.17 (0.83, 1.65) |
| Female | | 1.00 | 1.00 |
| Age Group | | | |
| > = 60 | | 1.20 (0.76, 1.90) | 1.20 (0.75, 1.92) |
| < 60 | | 1.00 | 1.00 |
| Education level | | | |
| At least high school | | 1.85 (1.06, 3.24) | 1.82 (1.03, 3.20) |
| Primary | | 1.10 (0.66, 1.82) | 1.06 (0.63, 1.76) |
| Never school | | 1.00 | 1.00 |
| Income | | | |
| > MWP | | 1.72 (0.51, 5.74) | 1.53 (0.43, 5.47) |
| < MWP | | 1.00 | 1.00 |
| Awareness that malaria could be prevented | | | |
| Yes | | 1.98 (0.79, 4.98) | 2.02 (0.79, 5.18) |
| No | | 1.00 | 1.00 |
| Hearing the malaria term | | | |
| No | | 0.84 (0.24, 2.97) | 0.92 (0.26, 3.29) |
| Yes | | 1.00 | 1.00 |
| Community level | | | |
| The availability health centre | | | |
| Yes | | - | 6.53 (1.03, 41.4) |
| No | | - | 1.00 |
| Geography | | | |
| Highland | | - | 3.59 (0.81, 15.8) |
| Lowland | | - | 1.00 |
| Access to the village | | | |
| Easy | | - | 4.40 (2.20, 8.82) |
| Difficult | | - | 1.00 |
| Community-level variance | | | |
| Variance | 3.211 | 3 | 2.367 |
| Intraclass correlation coefficient (ICC) | 49.39% | 47.69% | 41.84% |
| Proportional change in variance | Reference | 6.57% | 26.28% |
| Median odds ratio (MOR) | 5.53 | 5.22 | 4.34 |
| Akaike Information Criterion (AIC) | 4286.500 | 4314.672 | 4409.462 |
| Bayesian Information Criterion (BIC) | 4291.290 | 4319.455 | 4414.241 |

### 3.5 A two-level multilevel logistic regression model for $y_2$

Table 7 presents the multilevel logistic regression results for determinants of seeking malaria treatment at professional health facilities. The null model (Model I) revealed substantial village-level heterogeneity, with a community-level variance of 2.544 and an ICC of 43.61%, indicating strong clustering of treatment-seeking behavior across villages. In Model II, inclusion of individual-level covariates led to a minimal reduction in village-level variance (variance = 2.479; PCV = 2.56%). Gender was the only significant individual-level determinant, with males exhibiting lower odds of seeking professional treatment compared with females (AOR = 0.59; 95% CI: 0.38–0.92). Other individual-level variables were not statistically significant.

The full model (Model III) did not further reduce unexplained heterogeneity (variance = 2.571; ICC = 43.86%). Gender remained significant (AOR = 0.57; 95% CI: 0.36–0.89), while all other predictors were non-significant. The median odds ratio remained high across models (MOR ≈ 4.6), indicating persistent unobserved village-level effects. Model fit indices (AIC and BIC) increased with model complexity, suggesting limited additional explanatory power of the included covariates.

**Table 7.** Multilevel analysis for determinant factors associated with $y_2$ and predictors

| Variable | Model I (Null Model) | Model II (Individual Level) | Model III (Mixed Model) |
|---|---|---|---|
| Individual level | | | |
| Gender | | | |
| Male | | 0.59 (0.38, 0.92) | 0.57 (0.36, 0.89) |
| Female | | 1.00 | 1.00 |

| | | | |
|---|---|---|---|
| Age group | | | |
| > = 60 | | 1.24 (0.7, 2.19) | 1.22 (0.69, 2.17) |
| < 60 | | 1.00 | 1.00 |
| Education level | | | |
| At least high school | | 1.85 (0.9, 3.82) | 1.84 (0.89, 3.81) |
| Primary | | 1.02 (0.56, 1.86) | 0.99 (0.54, 1.82) |
| Never school | | 1.00 | 1.00 |
| Income | | | |
| > MWP | | 2.71 (0.31, 23.85) | 2.69 (0.3, 24.26) |
| < MWP | | 1.00 | 1.00 |
| Awareness malaria could be prevented | | | |
| Yes | | 1.38 (0.45, 4.23) | 1.34 (0.43, 4.16) |
| No | | 1.00 | 1.00 |
| Hearing malaria term | | | |
| No | | 0.39 (0.11, 1.3) | 0.39 (0.11, 1.33) |
| Yes | | 1.00 | 1.00 |
| Community level | | | |
| The availability health centre | | | |
| Yes | | - | 4.88 (0.49, 49.12) |
| No | | - | 1.00 |
| Geography | | | |
| Highland | | - | 1.91 (0.38, 9.68) |
| Lowland | | - | 1.00 |
| Access to village | | | |
| Easy | | - | 1.86 (0.92, 3.76) |
| Difficult | | - | 1.00 |
| Community-level variance | | | |
| Variance | 2.544 | 2.479 | 2.571 |
| ICC | 43.61% | 42.97% | 43.86% |
| PCV | Reference | 2.56% | -1.06% |
| MOR | 4.579 | 4.490 | 4.616 |
| AIC | 4828.220 | 4945.997 | 5023.028 |
| BIC | 4833.010 | 4950.779 | 5027.807 |

**Table 8.** Multilevel analysis for determinant factors associated with $y_3$ and predictors

| Variable | Model I (Null Model) | Model II (Individual Level) | Model III (Mixed Model) |
|---|---|---|---|
| Individual level | | | |
| Gender | | | |
| Male | | 1.12 (0.8, 1.57) | 1.10 (0.78, 1.56) |
| Female | | 1.00 | 1.00 |
| Age group | | | |
| > = 60 | | 1.27 (0.8, 2.02) | 1.27 (0.79, 2.03) |
| < 60 | | 1.00 | 1.00 |
| Education level | | | |
| At least high school | | 1.87 (1.06, 3.29) | 1.84 (1.03, 3.26) |
| Primary | | 1.07 (0.64, 1.78) | 1.03 (0.61, 1.73) |
| Never school | | 1.00 | 1.00 |
| Income | | | |
| > MWP | | 1.91 (0.56, 6.5) | 1.73 (0.47, 6.31) |
| < MWP | | 1.00 | 1.00 |
| Awareness malaria could be prevented | | | |
| Yes | | 1.62 (0.63, 4.14) | 1.64 (0.63, 4.29) |
| No | | 1.00 | 1.00 |
| Hearing malaria term | | | |
| No | | 0.79 (0.22, 2.81) | 0.86 (0.24, 3.09) |
| Yes | | 1.00 | 1.00 |
| Community level | | | |
| The availability health centre | | | |
| Yes | | - | 7.24 (1.14, 45.99) |
| No | | - | 1.00 |
| Geography | | | |
| Highland | | - | 3.34 (0.75, 14.78) |
| Lowland | | - | 1.00 |
| Access to village | | | |
| Easy | | - | 4.37 (2.18, 8.78) |
| Difficult | | - | 1.00 |
| Community-level variance | | | |
| Variance | 3.328 | 3.127 | 2.372 |
| ICC | 50.30% | 48.70% | 41.80% |
| PCV | Reference | 6.40% | 28.73 |

| | | | |
|---|---|---|---|
| MOR | 5.7 | 5.4 | 4.35 |
| AIC | 4309.441 | 4336.795 | 4431.401 |
| BIC | 4314.231 | 4341.577 | 4436.180 |

### 3.6 A two-level multilevel logistic regression model for $y_3$

Table 8 presents the multilevel logistic regression results for determinants of appropriate malaria treatment-seeking behavior. The null model (Model I) revealed substantial village-level clustering (variance = 3.328; ICC = 50.3%), indicating that over half of the variability was attributable to differences between villages. In Model II, including only individual-level variables, the community-level variance decreased slightly (variance = 3.127; PCV = 6.4%), with education emerging as a significant predictor: individuals with at least high school education were more likely to seek appropriate treatment than those with no formal education (AOR = 1.87; 95% CI: 1.06–3.29), while gender, age, income, malaria awareness, and prior exposure were not significant.

The full model (Model III) confirmed these associations: education (AOR = 1.84; 95% CI: 1.03–3.26), health centre availability (AOR = 7.24; 95% CI: 1.14–45.99), and easy access (AOR = 4.37; 95% CI: 2.18–8.78) remained significant. Community-level variance decreased to 2.372 (PCV = 28.73%), ICC to 41.8%, and the MOR declined from 5.7 to 4.35, indicating reduced unexplained heterogeneity. AIC and BIC increased slightly, but Model III best captured both individual and contextual influences on treatment-seeking behavior.

The ROC analysis based on predicted probabilities from the final multilevel model yielded an AUC of 0.884 (95% CI: 0.863–0.906), indicating acceptable discrimination between individuals with appropriate and inappropriate malaria treatment-seeking behavior as indicated in Figure 1.

The associations between predictors and the primary outcome are visually summarized in Figure 2. As illustrated, community-level factors such as the presence of a health centre demonstrated a strong positive effect (AOR = 7.24), although the wide CI (1.14–45.99) suggested variability in this estimate, likely due to the small number of village clusters (N = 25). Conversely, individual education showed a tighter CI, indicating a more precise estimate of the effect.

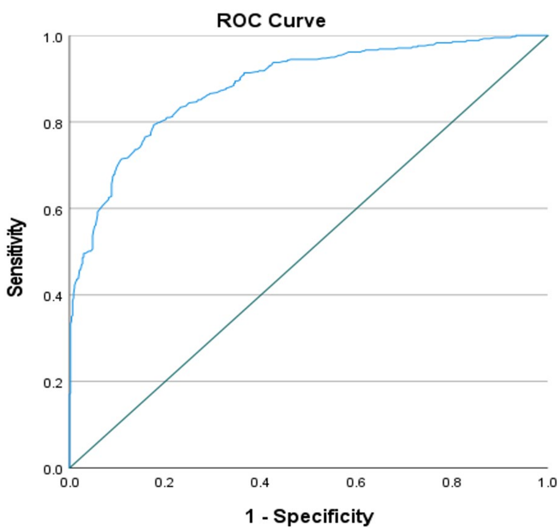


**Figure 1.** Receiver Operating Characteristic (ROC) curve for the multilevel logistic regression model predicting reported appropriate malaria treatment-seeking behavior
Note: Diagonal segments are produced by ties.

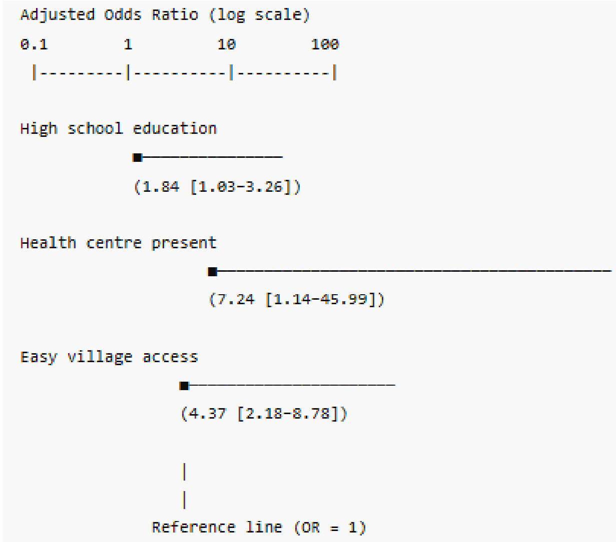


**Figure 2.** Forest plot displaying the adjusted odds ratio and 95% confidence interval for determinants of reported appropriate malaria treatment-seeking behavior

## 4. DISCUSSION

To our knowledge, this is the first study to model the determinants of self-reported appropriate Malaria-treatment seeking in the rural, high-transmission setting of NTT using a two-level multilevel logistic regression framework. This study applied Andersen's Behavioral Model to dissect the hierarchical determinants of reported appropriate malaria treatment-seeking behavior in rural NTT. The findings underscore a critical interplay between individual predisposing factors and community enabling factors. While high school education—a key predisposing factor—significantly increased the likelihood of appropriate care (AOR = 1.84), the analysis revealed that enabling factors exerted a far greater influence. The strong association with health centre availability (AOR = 7.24) and easy village access (AOR = 4.37) suggests that in this high-endemic setting, the primary barrier to elimination is not merely a lack of intent (predisposing), but a deficit in structural opportunity (enabling).

This study demonstrated that educational attainment emerged as a robust predictor, with individuals who completed at least high school exhibiting significantly higher odds of seeking appropriate treatment (AOR = 1.84). This finding aligns with the health belief model, which posits that the decision to seek treatment is influenced by an individual's perception of illness severity and susceptibility [39]. Higher education likely serves as a proxy for health literacy, enhancing an individual's ability to recognize malaria symptoms early and navigate the healthcare system effectively [22, 37, 40-42]. Educated individuals are better equipped to understand the risks of complications if malaria is untreated, prompting quicker medical visits. This highlights the need for targeted interventions. In communities with low formal education, as shown in rural NTT [43], reliance on written materials is insufficient. Strategies must utilize community-based education, local media, and Community Health Workers to bridge the literacy gap and reduce reliance on self-medication [44, 45]. This study highlights the importance of an intervention strategy to reach the rural community with a low education level. Community-based education, the use of local media, and the involvement of health workers could assist in tackling limited health literacy and intensifying access to accurate information. Therefore, improving appropriate malaria treatment-seeking behavior depends not only on service facilities but also on an inclusive and sustainable approach to health education.

A striking finding of this study is that structural factors at the community level demonstrated substantially stronger effects than individual characteristics. The availability of a health centre within a village was the strongest predictor of appropriate treatment-seeking behavior (AOR = 7.24). This magnitude suggests that in rural NTT, service utilization is driven by structural opportunity. This supports the "Distance Decay" hypothesis, where utilization declines exponentially as the effort required to reach a facility increases [40, 46]. Our finding aligns with studies from other archipelago nations and Sub-Saharan Africa, which consistently show that physical proximity is often the "rate-limiting step" for malaria treatment [20, 27, 47, 48]. Even with high health literacy (individual factor), patients are unlikely to seek appropriate care if the supply-side logistics (facility availability) are absent. This highlights that health education campaigns must be matched with infrastructure investment to be effective.

In the context of rural NTT, where the terrain is often rugged and public transport is unreliable, as well as relying on walking to reach health facilities [49], the presence of a facility within the village effectively removes the "transaction costs" of seeking care. When a Puskesmas or Pustu (subsidiary health centre) is locally available, the direct costs (transport fares) and indirect opportunity costs (lost wages, time away from agriculture) are minimized. Consequently, the threshold for seeking care is lowered; individuals do not wait for symptoms to become severe before visiting a doctor. Conversely, in villages without a facility, the physical and financial burden of travel likely acts as a deterrent, leading residents to rely on self-medication or traditional healers as a "first line" response to their malaria, as shown in the literature [50].

The distinction between Highland and Lowland communities in NTT extends beyond topography to cultural and behavioral domains [51]. Highland communities often maintain stronger adherence to traditional customs (*adat*), where illness is frequently interpreted through spiritual lenses requiring ancestral appeasement before medical intervention [52]. Furthermore, the agricultural practice of residing in semi-permanent 'garden houses' (*Rumah Kebun*) during planting and harvest seasons is more prevalent in Highland areas [53]. This practice physically isolates families from village centers where health information is disseminated, creating a 'double burden' of geographic remoteness and cultural insulation that delays appropriate treatment-seeking.

It is important to acknowledge the wide confidence interval associated with this finding (95% CI: 1.14-45.99). This width is likely a statistical artifact resulting from the sample size at the second level of analysis (25 villages) [54]. While the small number of clusters reduces the precision of the point estimate, the lower bound of the interval (1.14) remains above 1.0, confirming that the positive association is statistically significant and robust. This suggests that while we cannot pinpoint the exact magnitude of the benefit (whether it is 7-fold or merely 2-fold), we can confidently conclude that the presence of local infrastructure is a critical determinant of service uptake.

Furthermore, the multilevel analysis showed that residents in villages with easy access were over four times more likely to seek appropriate treatment (AOR = 4.37) highlights the critical role of transport infrastructure in malaria control. This is particularly relevant in the context of NTT, where the topography is dominated by mountainous terrain and scattered islands. Many remote villages in NTT are connected only by poorly maintained or unpaved roads that are difficult for motor vehicles to navigate, especially during the rainy season. As a result, residents often walk long distances to reach the nearest passable road and rely on limited and relatively expensive private informal transport services (e.g., motorcycle taxis) to access health facilities [55, 56]. Furthermore, this infrastructure deficit creates a "seasonal trap." Malaria transmission in NTT typically peaks during the rainy season; however, this is precisely when unpaved village roads are most likely to become impassable due to mud or flooding. This suggests that the barrier is not merely the static distance to a clinic, but the dynamic difficulty of travel, which worsens exactly when the need for treatment is highest. These physical barriers likely contribute to the "Second Delay" (delay in reaching the health facility), discouraging patients from seeking formal care until symptoms become severe.

From a methodological standpoint, the findings validate the use of multilevel modeling to disentangle individual decision-making processes from structural village-level influences. Ignoring this hierarchical structure would likely have led to biased effect estimates and an underestimation of contextual impacts. In practical terms, the results imply that interventions aimed at improving malaria treatment outcomes should prioritize both educational advancement and community-level infrastructure development. While education enhances individual capacity for informed health decisions, the presence and accessibility of health facilities fundamentally condition whether such decisions can be acted upon.

Finally, it was important to acknowledge that the outcome measure in this study was based on self-reported behavior obtained through survey interviews rather than directly observed clinical actions or medical records. While self-reports were a standard method in demographic health surveys, they were subject to recall bias (participants might not remember details accurately) and social desirability bias (participants may report 'appropriate' behavior to please the interviewer). Therefore, the findings should be interpreted as determinants of the reported intent or recalled practice of treatment-seeking, which serves as a proxy for actual health utilization behavior. Then, the use of official village registries as the sampling frame ensured the representativeness of the settled population but may have excluded unregistered individuals or those residing temporarily in farming locations (*kebun*) away from the main village settlement. Consequently, the findings primarily reflect the treatment-seeking behavior of the permanent, registered population. Moreover, while the study focused on a high-endemic rural setting in NTT, the results might not be fully generalizable to urban settings or regions with different topographical challenges. However, these findings were likely highly relevant to other remote, high-burden regions in Eastern Indonesia. Future research could incorporate longitudinal designs or spatial modeling to capture these dynamic geographic effects more explicitly.

## 5. CONCLUSIONS

This study successfully applied a two-level multilevel logistic regression model to quantify the stochastic determinants of appropriate malaria treatment-seeking behavior in the high-endemic region of NTT. By accounting for the hierarchical architecture of the data—where individuals were nested within village clusters—the model corrected for the intraclass correlation that typically biases standard single-level analyses. The mathematical analysis revealed that treatment-seeking behavior was not merely a function of individual decision-making but was heavily constrained by structural parameters. While individual education acted as a significant predisposing factor (AOR = 1.84), the magnitude of community-level structural determinants is substantially greater. The presence of a health centre (AOR = 7.24) and the ease of village access (AOR = 4.37) emerged as the dominant drivers of appropriate care utilization. These findings empirically demonstrated that the "friction of distance" and infrastructure deficits constituted the primary bottlenecks in the malaria elimination system.

Methodologically, this research confirmed that ignoring village-level heterogeneity in public health modeling leads to ecological fallacies and ineffective policy design. The significant variance attributed to the community level underscores that malaria elimination in rural archipelagic settings is fundamentally a system engineering challenge as much as it is a medical one.

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