e-ISSN: 2774-2962

Community Medicine and Education Journal

CMEJ

https://hmpublisher.com/index.php/cmej

Patient Cognition Over Social Context: A Theory of Planned Behavior Analysis Reveals Attitude as the Dominant Predictor of Primaquine Adherence Intention for *Plasmodium vivax* Radical Cure in Hyperendemic Papua, Indonesia

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ARTICLE INFO

Keywords:
Malaria
Medication adherence
Plasmodium vivax
Primaquine
Theory of planned behavior

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All authors have reviewed and approved the final version of the manuscript.

https://doi.org/10.37275/cmej.v6i2.803

A B S T R A C T

Relapsing *Plasmodium vivax* malaria remains a major obstacle to malaria elimination, with its treatment critically dependent on patient adherence to a 14-day primaquine regimen for radical cure. In hyperendemic regions like Papua, Indonesia, non-adherence is a primary cause of treatment failure. This study applied the Theory of Planned Behavior (TPB) to identify the key psychosocial determinants of adherence intention in this population to inform targeted public health interventions. A descriptive analytical study with a cross-sectional design was conducted in the East Sentani District of Papua, Indonesia, from February to April 2024. A total of 100 adult patients diagnosed with *P. vivax* malaria were recruited via consecutive sampling. A culturally adapted, validated questionnaire was used to measure the TPB constructs: attitude, subjective norms, and perceived behavioral control (PBC), alongside behavioral intention. Initial data analysis revealed quasi-complete separation, necessitating the use of a penalized logistic regression model (Firth's method) to generate stable and reliable estimates of association. The penalized logistic regression model was statistically significant and explained a considerable portion of the variance in adherence intention (Nagelkerke R^2 = 0.482). After controlling for other variables, a patient's personal attitude toward the treatment was the only significant predictor of their intention to complete the primaquine regimen. A more positive attitude was strongly associated with a higher intention to adhere (Odds Ratio [OR] = 5.21, 95% Confidence Interval [CI]: 2.15 - 12.67; $p < 0.001$). In contrast, neither subjective norms (OR = 1.12, 95% CI: 0.88 - 1.43; $p = 0.354$) nor perceived behavioral control (OR = 1.35, 95% CI: 0.91 - 2.01; $p = 0.138$) demonstrated a significant independent influence on behavioral intention. In conclusion, patient attitude—the individual's cognitive and affective evaluation of the treatment—is the primary driver of the intention to adhere to the 14-day primaquine regimen in this Papuan cohort. While social context and perceived barriers should not be disregarded, these findings strongly suggest that public health strategies must prioritize patient-centered educational interventions that cultivate a deep understanding of the biological necessity of radical cure to foster positive, resilient attitudes towards treatment completion.

1. Introduction

Malaria, a parasitic disease transmitted by Anopheles mosquitoes, continues to be a formidable global health challenge, inflicting significant morbidity and mortality worldwide.[1] While international efforts have made substantial inroads against *Plasmodium falciparum*, the most lethal of the human malaria parasites, its resilient counterpart, *Plasmodium vivax*, presents a distinct and persistent set of challenges that complicate elimination goals. *P. vivax* is the most geographically widespread human malaria parasite, placing an estimated 2.5 billion people at risk of infection.[2] In 2023, it was responsible for millions of clinical cases globally, representing the majority of the malaria burden outside the African continent.

The Indonesian archipelago, particularly its eastern provinces, serves as a major global epicenter for *P. vivax* transmission. Despite national

commitments to malaria elimination, recent epidemiological trends are concerning. The Indonesian Ministry of Health reported a significant increase in malaria cases from 254,055 in 2020 to 443,530 in 2022. An overwhelming majority of this burden is concentrated in Eastern Indonesia, with the province of Papua alone accounting for over 80% of the national total, reporting 356,889 cases in 2022.[3] This state of hyperendemicity in Papua not only causes immense suffering for its population but also acts as a persistent parasite reservoir, jeopardizing Indonesia's national target of achieving malaria elimination by 2030. The interruption of local transmission of all human malaria species, including *P. vivax*, is a prerequisite for achieving this goal.

The primary biological feature that distinguishes *P. vivax* from *P. falciparum* and makes it so difficult to eliminate is its ability to form dormant, quiescent parasite stages in the liver, known as hypnozoites.[4] Following an infectious mosquito bite, sporozoites invade hepatocytes. While some mature directly into blood-stage parasites, causing the acute febrile illness, others transform into hypnozoites, where they can remain biologically silent for weeks, months, or even years. These dormant forms are invisible to the immune system and are unaffected by standard blood-stage antimalarial drugs. Periodically, these hypnozoites can reactivate, initiating a new wave of merozoite release into the bloodstream and causing a full clinical relapse of malaria, even without a new mosquito bite.

This cycle of relapse is the engine of *P. vivax* persistence. It contributes significantly to cumulative patient morbidity, including chronic and severe anemia, developmental impairment in children, and increased susceptibility to other infections.[5] From a public health perspective, relapses ensure that an infected individual can remain a source of transmission for the wider community over a prolonged period, sustaining the parasite reservoir and making it exceedingly difficult for control programs to break the cycle of infection. Therefore, the elimination of *P. vivax* is biologically impossible without a therapeutic strategy that explicitly targets and eradicates the dormant liver-stage hypnozoites.

The current standard of care to achieve this is known as a "radical cure". This is a two-part treatment. First, a 3-day course of a blood-stage schizonticide, typically an Artemisinin-based Combination Therapy (ACT), is administered to clear the acute infection and resolve clinical symptoms. Second, a 14-day course of primaquine, an 8-aminoquinoline compound, is required. Primaquine is one of the only widely available drugs with potent activity against hypnozoites. Its metabolites are thought to generate reactive oxygen species within the infected hepatocyte, inducing lethal oxidative stress in the dormant parasite. The 14-day duration is not arbitrary; it is the period required to ensure sufficient cumulative drug exposure to eliminate the entire hypnozoite population.[6]

While the radical cure regimen is highly effective when completed, its extended duration presents a profound behavioral challenge.[7] Patients typically feel clinically well within a few days of starting the ACT, as their fever and other symptoms resolve. This rapid improvement can severely diminish their motivation to continue taking a second drug, primaquine, for an additional two weeks, particularly if they experience side effects such as gastrointestinal upset. This phenomenon, where the perceived need for medication declines far more rapidly than the prescribed course of treatment, creates a critical "behavioral bottleneck" that systematically undermines the effectiveness of malaria control programs.

Incomplete or poor adherence to the 14-day primaquine regimen leads directly to treatment failure. This failure manifests as recurrent relapses in the patient, which places a continued burden on the health system, increases the individual's risk of long-term complications, and, most critically, sustains the parasite reservoir, allowing for continued transmission within the community. Consequently, understanding and improving patient adherence to primaquine is not merely a matter of clinical management but a central and non-negotiable pillar of any serious public health

strategy aimed at *P. vivax* malaria elimination.[8]

Human behavior is a complex interplay of internal psychological processes and external environmental factors. To design effective interventions that promote medication adherence, it is essential to move beyond simplistic assumptions about patient knowledge and employ robust theoretical frameworks that can systematically identify the key drivers of behavior. The Theory of Planned Behavior (TPB), developed by Icek Ajzen, is one of the most influential and well-validated models for predicting and understanding human social behavior, and it has been widely applied to health-related actions.[9] The TPB posits that the most direct determinant of a specific behavior is one's intention to perform that behavior. This behavioral intention, in turn, is predicted by three core psychological constructs: (1) Attitude toward the Behavior: This refers to an individual's overall positive or negative evaluation of performing the behavior. It is formed from their beliefs about the likely outcomes or consequences of the behavior, for instance, "Completing the primaquine course will prevent me from getting sick again and allow me to work," and their evaluation of those consequences; (2) Subjective Norms: This construct captures the perceived social pressure to perform or not perform the behavior. It is determined by an individual's beliefs about whether significant others, such as family, doctors, and community leaders, approve or disapprove of the behavior, combined with their motivation to comply with the wishes of these referents; (3) Perceived Behavioral Control (PBC): This refers to an individual's perception of the ease or difficulty of performing the behavior. It encompasses their assessment of both internal factors, including self-efficacy, knowledge, and skills, and external factors, including access to medication, time, and resources, that may facilitate or impede the action. PBC can influence behavior directly or indirectly by shaping intention.

By applying the TPB framework, it is possible to quantitatively assess which of these three pillars—personal attitude, social pressure, or perceived control—is the most influential driver of the intention to adhere to primaquine in a specific population. This knowledge is invaluable for tailoring interventions to target the most critical leverage points for behavioral change, ensuring that limited public health resources are directed with maximum impact.[10]

Despite the universally recognized importance of primaquine adherence, there is a significant gap in the literature regarding the systematic application of behavioral theory to understand this challenge within the unique and demanding context of hyperendemic Papua, Indonesia. Most existing research has focused on clinical efficacy, epidemiology, or logistical barriers, often leaving the psychosocial "why" behind patient behavior largely underexplored. This study was designed to fill this critical knowledge gap. Therefore, the aim of this research was to analyze the independent influence of the three core constructs of the Theory of Planned Behavior—attitude, subjective norms, and perceived behavioral control—on the intention of *P. vivax* malaria patients to adhere to the full 14-day primaquine regimen in the East Sentani District, Papua. The novelty and significance of this study lie in its rigorous application of a leading behavioral science framework to a major public health crisis in one of the world's most intractable malaria hotspots. By moving beyond anecdotal observations and quantitatively dissecting the psychosocial architecture of adherence intention, this research provides empirical, actionable evidence for policymakers and program implementers. Identifying the most potent psychological predictor for intervention is a crucial first step in designing targeted, resource-efficient, and ultimately more effective public health strategies to support patients, improve radical cure rates, and accelerate progress toward the goal of malaria elimination in Indonesia and beyond.

2. Methods

This study utilized a descriptive analytical design with a cross-sectional approach to investigate the determinants of primaquine adherence intention. Data were collected from each participant at a single point

in time to assess the statistical relationships between the independent variables (TPB constructs: attitude, subjective norms, PBC) and the dependent variable (behavioral intention). The research was conducted between February and April 2024 in the East Sentani District, located in the Jayapura Regency of Papua Province, Indonesia. This setting was purposively selected due to its status as a hyperendemic malaria region. Papua Province consistently reports the highest Annual Parasite Incidence (API) in Indonesia, making it a priority area for national malaria elimination efforts. The district is served by several primary healthcare centers (Puskesmas), which are the frontline facilities for malaria diagnosis and treatment, providing a suitable environment for patient recruitment.

The target population for this study consisted of all adult patients diagnosed with *P. vivax* malaria receiving care at Puskesmas within the East Sentani District. A consecutive sampling strategy was employed, wherein every patient who met the eligibility criteria during the three-month study period was invited to participate until the target sample size was reached. This non-probability sampling method is practical for clinical settings and is generally considered superior to convenience sampling in reducing selection bias. The inclusion criteria for participation were: (1) adult patients aged 18 years or older; (2) a confirmed mono-infection of *P. vivax* malaria via microscopic examination or a rapid diagnostic test (RDT); (3) having been prescribed a 14-day course of primaquine for radical cure; and (4) the ability and willingness to provide informed consent. The exclusion criteria were: (1) pregnancy, as primaquine is contraindicated; (2) known Glucose-6-Phosphate Dehydrogenase (G6PD) deficiency, due to the risk of drug-induced hemolysis; (3) severe or complicated malaria requiring hospitalization; and (4) any cognitive or communication impairment that would prevent the participant from understanding and completing the questionnaire. The exclusion of patients with known G6PD deficiency was a pragmatic choice to focus the behavioral analysis on the cohort for whom primaquine is the standard recommended treatment, though this is acknowledged as a significant limitation affecting the generalizability of the findings.

A post-hoc power analysis was conducted using G*Power 3.1 software to assess the statistical power of our sample size (N=100) for the primary analysis. For a logistic regression model with three predictor variables, an alpha of 0.05, and a two-tailed test, a sample of 100 participants provides 85% power to detect a medium effect size (Odds Ratio ≈ 2.5), which is considered adequate for identifying meaningful relationships in behavioral research. The primary data collection tool was a structured questionnaire developed specifically for this study, based on the theoretical tenets of the TPB and following established construction guidelines. The instrument consisted of two sections: sociodemographic characteristics and items measuring the TPB constructs. The development process involved several stages to ensure validity. An initial version of the questionnaire was developed in English. This was translated into Indonesian by a certified bilingual health expert and subsequently back-translated into English by an independent translator to ensure semantic and conceptual equivalence.

To ensure cultural adaptation, the Indonesian version of the questionnaire was reviewed by a panel of local experts, including a public health official, a clinician working in the local Puskesmas, and a community leader from Sentani. This panel reviewed the items for cultural appropriateness, clarity, and resonance with local idioms and understandings of health and illness. Following this, cognitive interviews were conducted with five non-participating malaria patients to confirm that the questions were understood as intended. For instance, questions about "subjective norms" were framed using locally relevant referents like "family, the doctor at the Puskesmas, and the village health volunteer (kader)."

All items measuring TPB constructs were scored on a 5-point Likert scale. The operationalization was as follows: (1) Behavioral Intention (Dependent Variable):

Measured with 3 items assessing the participant's stated likelihood of completing the full 14-day course, such as "I plan to take my primaquine pills every day for the full 14 days, no matter what."; (2) Attitude (Independent Variable): Measured with 5 semantic differential scale items rating the act of "Completing the full 14-day primaquine treatment" on bipolar adjectives, including Beneficial–Harmful, Wise–Foolish, and Necessary–Unnecessary; (3) Subjective Norms (Independent Variable): Measured with 4 items assessing perceived social pressure and approval from significant others, such as "Most people who are important to me think I should complete the full 14-day treatment."; (4) Perceived Behavioral Control (PBC) (Independent Variable): Measured with 4 items assessing perceived ease, difficulty, and confidence in adhering to the regimen. An example item is "For me to complete the full 14-day primaquine treatment is..." rated from Very Difficult to Very Easy.

Data were collected by trained researchers in a private area of the health center after the patient had received their diagnosis and prescription. The questionnaire was primarily self-administered, but researchers were available to read the questions aloud and record the answers for participants with low literacy, following a standardized, non-leading protocol to ensure consistency. Prior to the main study, a pilot test was conducted on 20 *P. vivax* patients in a neighboring district with similar demographics. Data from the main study sample (N=100) were used to confirm the internal consistency reliability of the scales using Cronbach's alpha. The results demonstrated excellent reliability for all scales: Behavioral Intention ($\alpha = 0.92$), Attitude ($\alpha = 0.89$), Subjective Norms ($\alpha = 0.85$), and Perceived Behavioral Control ($\alpha = 0.88$), all of which are well above the accepted threshold of 0.70.

This study was conducted in strict adherence to the ethical principles outlined in the Declaration of Helsinki. Full ethical approval for the research protocol, consent forms, and data collection instruments was obtained from the Health Research Ethics Committee of the University of Cenderawasih, Jayapura, Indonesia (Approval No. 101/KEPK-FKM UC/2024). All potential participants received a detailed verbal and written explanation of the study's purpose, procedures, and voluntary nature. It was explicitly stated that their decision would not impact the quality of their medical care. Written informed consent was obtained from every participant prior to enrollment. All data were fully anonymized using unique identification codes to protect participant confidentiality.

All data were coded and analyzed using SPSS Statistics for Windows, Version 26.0 (IBM Corp., Armonk, NY, USA). The analysis proceeded in stages. First, descriptive statistics (frequencies, percentages, means, standard deviations) were calculated to summarize the sample's characteristics and the distribution of scores on the TPB constructs. Second, bivariate associations between the TPB predictor constructs and behavioral intention were assessed using Spearman's rank-order correlation, chosen due to the non-normal distribution of the data as confirmed by the Kolmogorov-Smirnov test ($p < 0.001$).

The primary analysis aimed to determine the independent predictive power of each TPB construct on behavioral intention. An initial ordinal logistic regression model revealed signs of quasi-complete separation in the data—a condition where a predictor variable nearly perfectly predicts the outcome, leading to unstable and infinitely large parameter estimates. This was evidenced by implausibly large odds ratios and standard errors in the initial output. Cross-tabulations confirmed that high scores on the Attitude scale were almost perfectly predictive of high scores on the Intention scale.

To address this statistical issue and generate reliable estimates, the primary multivariate analysis was re-conducted using a penalized logistic regression model with Firth's correction. Firth's method is a well-established technique for handling separation in logistic regression models by introducing a small bias into the likelihood function, which in turn produces finite, stable parameter estimates. This analysis was performed with the Behavioral Intention score as the

dependent variable and the composite scores for Attitude, Subjective Norms, and PBC as the independent continuous predictors. The model's overall significance was assessed using a likelihood ratio test, and the proportion of variance explained was estimated using the Nagelkerke R^2 value. For each predictor, the regression coefficient (β), p-value, odds ratio (OR), and 95% confidence interval (CI) were calculated. Statistical significance for all tests was set at an alpha level of $p < 0.05$.

3. Results

A total of 100 eligible adult patients with *P. vivax* malaria were enrolled in the study. The characteristics of the sample are detailed in Table 1. The sample was majority female (60.0%). The predominant age group was early adulthood (26–35 years; 43.0%), followed closely by late adolescence (18–25 years; 38.0%). A notable characteristic of the sample was the high level of educational attainment; 66.0% had completed Senior High School, and 31.0% had attended college or university. Only 3% of the sample had a junior high school education or less. The most common occupation was laborer/farmer (35.0%), followed by students (25.0%). The majority of respondents (58.0%) reported a monthly household income below IDR 3,000,000. Indicative of the endemic setting, a substantial portion of the sample (45.0%) reported having had at least one prior episode of malaria.

Table 1. Sociodemographic and Clinical Characteristics of Study Participants (N=100)

VARIABLE	CATEGORY	FREQUENCY (N)	PERCENTAGE (%)
Gender	Male	40	40.0%
	Female	60	60.0%
Age Group (Years)	18–25	38	38.0%
	26–35	43	43.0%
	36–45	11	11.0%
	> 46	8	8.0%
Highest Education Level	Elementary School	1	1.0%
	Junior High School	2	2.0%
	Senior High School	66	66.0%
	College/University	31	31.0%
Occupation	Laborer / Farmer	35	35.0%
	Student	25	25.0%
	Civil Servant / Private Employee	22	22.0%
	Homemaker	12	12.0%
	Unemployed	6	6.0%
Monthly Income	< IDR 3,000,000	58	58.0%
	IDR 3,000,000 - 5,000,000	32	32.0%
	> IDR 5,000,000	10	10.0%
History of Malaria	First Episode	55	55.0%
	One Previous Episode	28	28.0%
	Two or More Previous Episodes	17	17.0%

Table 2 presents the descriptive statistics for the four TPB constructs. Participants reported very high mean scores for both Attitude (M = 4.85, SD = 0.36) and Behavioral Intention (M = 4.78, SD = 0.42). This indicates overwhelmingly positive evaluations of the treatment and very strong intentions to adhere. The low standard deviations for these scales reflect a ceiling effect, with limited variability at the upper end of the scale. Scores for Subjective Norms (M = 4.12, SD = 0.65) and Perceived Behavioral Control (M = 4.35, SD = 0.58) were also high but showed slightly more variability.

Table 2. Descriptive Statistics and Reliability of TPB Construct Scales (N=100)

CONSTRUCT	ITEMS	SCALE RANGE	MEAN SCORE (1-5)	STD. DEV (SD)	RELIABILITY (CRONBACH'S A)
Behavioral Intention	3	1–5	4.78	0.42	0.92 (Excellent)
Attitude	5	1–5	4.85	0.36	0.89 (Good)
Subjective Norms	4	1–5	4.12	0.65	0.85 (Good)
Perceived Behavioral Control	4	1–5	4.35	0.58	0.88 (Good)

Spearman's rank-order correlation analysis was conducted to examine the initial relationships between the predictor constructs and behavioral intention (Table 3). All three TPB constructs were positively and significantly correlated with the intention to adhere. The strongest association was between Attitude and Behavioral Intention ($r_s = 0.689$, $p < 0.001$), indicating a very strong positive relationship. Perceived Behavioral Control also showed a strong positive correlation with intention ($r_s = 0.512$, $p < 0.001$). Subjective Norms had a moderate but still highly significant positive correlation ($r_s = 0.345$, $p < 0.001$). These findings suggest that while all three constructs are related to intention, a patient's personal attitude is the most powerful correlate.

To determine the independent predictive power of each TPB construct while controlling for the others, and to overcome the issue of quasi-complete separation in the data, a penalized logistic regression using Firth's method was performed. The overall model containing the three predictors was statistically significant, indicating that it provided a significantly better fit than a null model ($x^2(3) = 55.45$, $p < 0.001$). The model explained a substantial proportion of the variance in adherence intention, with a Nagelkerke R^2 of 0.482. The parameter estimates from the final model are presented in Table 4. These results provide the core findings of the study.

The analysis decisively identifies Attitude as the sole significant independent predictor of the intention to adhere to primaquine therapy. The positive regression coefficient ($\beta = 1.651$) was highly significant ($p < 0.001$). The corresponding odds ratio (OR) was 5.21, with a 95% confidence interval that did not include 1 (95% CI: 2.15 - 12.67). This indicates that for every one-unit increase in the attitude score (on the 5-point scale), the odds of a patient having a higher intention to adhere increased by a factor of 5.21, holding the other variables constant. This finding demonstrates that a patient's personal positive evaluation of the treatment is a powerful and primary driver of their commitment.

Table 3. Spearman's Rank-Order Correlation Matrix of TPB Constructs (N=100)

	1. BEHAVIORAL INTENTION	2. ATTITUDE	3. SUBJECTIVE NORMS	4. PERCEIVED CONTROL
1. Behavioral Intention	1.000			
2. Attitude	0.689***	1.000		
3. Subjective Norms	0.345***	0.287**	1.000	
4. Perceived Control	0.512***	0.455***	0.398***	1.000

Note: Values represent Spearman's rank-order correlation coefficients (r_s).

Significance Levels: *** Correlation is significant at the 0.001 level (2-tailed). ** Correlation is significant at the 0.01 level (2-tailed).

Color Intensity Guide:

Weak Moderate Strong Very Strong

In stark contrast, neither Subjective Norms nor Perceived Behavioral Control emerged as significant predictors in the multivariate model. For Subjective Norms, the odds ratio was close to null (OR = 1.12, p = 0.354), indicating that perceived social pressure had no significant independent effect on adherence intention when attitude and PBC were accounted for. Similarly, for Perceived Behavioral Control, despite its strong bivariate correlation with intention, its effect became non-significant in the full model (OR = 1.35, p = 0.138). This suggests that once a patient's strong personal attitude is considered, their perceived control over practical barriers does not add significant additional explanatory power to their intention.

4. Discussion

The central and unequivocal finding of this study is the predominance of patient attitude as the primary psychosocial driver of the intention to adhere to the 14-day primaquine regimen for *P. vivax* radical cure in our Papuan cohort.[11] After employing a robust penalized regression model to ensure the stability of our findings, the results demonstrate that a patient's personal, positive evaluation of the treatment is a powerful and statistically significant predictor of their commitment to therapy. In contrast, the influences of perceived social pressure (subjective norms) and perceived practical control (PBC) were rendered non-significant in the multivariate context. This result provides a clear and actionable insight: to improve primaquine adherence in this hyperendemic setting, interventions must first and foremost succeed in shaping, reinforcing, and sustaining a positive patient attitude towards the treatment's necessity, benefits, and wisdom.[12]

Table 4. Penalized Logistic Regression Predicting Behavioral Intention to Adhere to Primaquine (N=100)

PREDICTOR VARIABLE	B (ESTIMATE)	P-VALUE	ODDS RATIO (OR)	ODDS RATIO PLOT (95% CI)
☆ **Attitude** Primary significant predictor	1.651	< 0.001***	5.21	
Subjective Norms	0.113	0.354	1.12	
Perceived Behavioral Control	0.300	0.138	1.35	

Model Fit Statistics:

- **Chi-Square (χ^2):** 55.45
- **Model p-value:** < 0.001
- **Pseudo R-Square (Nagelkerke):** 0.482

How to Read the Plot:

- The colored dot represents the calculated **Odds Ratio (OR)**.
- The horizontal bar is the **95% Confidence Interval (CI)**.
- The red line at 1.0 indicates **no effect**. CIs that cross this line are not statistically significant.

To fully appreciate the significance of this finding, it is crucial to connect the psychological construct of "attitude" to the underlying biological imperative of radical cure. The unique pathophysiology of *P. vivax* is defined by the hypnozoite, the dormant parasitic form that resides silently within liver cells long after the acute, symptom-causing blood-stage infection has been cleared.[13] While the 3-day ACT regimen is highly effective at resolving clinical symptoms, it is completely inert against these latent hypnozoites. If left untreated, they will inevitably reactivate, leading to a cascade of merozoite release and a full-blown clinical relapse. This cycle of relapse is the engine of *P. vivax* morbidity and transmission. Primaquine is the essential therapeutic tool that targets this biological vulnerability. Its metabolites are believed to function by generating a high level of oxidative stress within the infected hepatocyte, creating a hostile environment that is lethal to the dormant parasite.[14] The 14-day course is the validated duration required to achieve sufficient cumulative drug exposure to eradicate the entire hypnozoite reservoir.

From this perspective, a patient's "attitude" can be conceptualized as the psychological manifestation of their understanding and acceptance of this complex biological reality. A positive attitude—characterized by beliefs that the full 14-day treatment is necessary, beneficial, and wise—is likely a proxy for the patient having internalized the critical concept that feeling better is not the same as being cured. Such a patient understands that an invisible threat persists in their liver and that primaquine is the only available tool to eliminate it, thus preventing future illness. Conversely, a neutral or negative attitude may reflect a superficial understanding, where the cessation of symptoms is incorrectly equated with the eradication of the infection.[15] From this latter viewpoint, continuing a two-week therapy with potential side effects appears burdensome, illogical, and unnecessary. Our finding demonstrates that this internal cognitive and affective state (attitude) is the critical link between receiving a prescription and forming the resilient intention required to use it correctly to achieve a biological cure.[16]

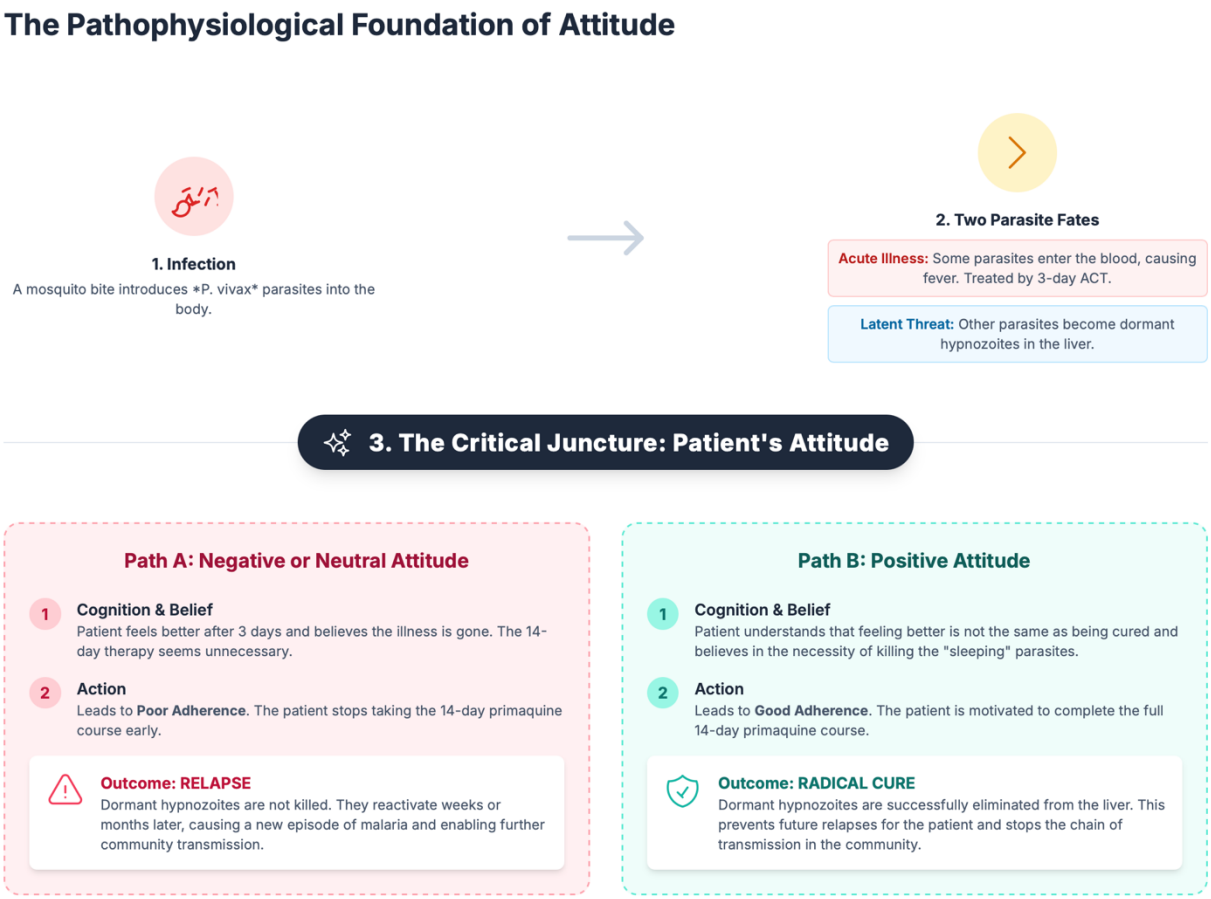

Figure 1. Pathophysiological foundation of attitude.

The lack of a significant independent effect of subjective norms and perceived behavioral control warrants a nuanced interpretation within the sociocultural and health system context of Papua. The non-significance of subjective norms does not necessarily mean that family and healthcare providers are unsupportive. Indeed, the high mean score for this construct suggests that patients generally perceive social encouragement. However, it may be that in a region where malaria is deeply endemic and a common part of life, social encouragement to take medicine is a ubiquitous, non-discriminating background factor. It may not be a specific pressure that differentiates individuals with high versus low adherence intention. An alternative interpretation is that while social support is important for seeking initial treatment, the day-to-day, unobserved act of taking a pill for two weeks is ultimately framed as a matter of personal responsibility, where the individual's own beliefs (attitude) supersede perceived social expectations.[17] This aligns with research in other chronic diseases where internal motivation is often a stronger predictor of long-term adherence than external social pressure.

The non-significance of perceived behavioral control (PBC) in the multivariate model is particularly intriguing. This suggests that for this specific cohort, practical barriers were not the primary determinant of intention. This could be a reflection of the local health system, where malaria diagnosis and treatment are typically provided free of charge through the *Puskesmas*, effectively removing major logistical and financial hurdles. If most patients feel confident that they can complete the treatment if they choose to, then PBC would not vary enough to be a significant

predictor of their choice (intention). The problem, as our data show, is not about the perceived ability to adhere, but the will to adhere, which is governed by attitude. This finding is critical for program planning, as it implies that resources may be more effectively invested in high-quality patient education rather than on interventions aimed solely at overcoming logistical barriers that may not be primary drivers of non-adherence in this group.[18]

The application of the TPB to medication adherence has a rich history across various diseases, with the relative importance of each construct varying by behavior and context. Our finding of the supremacy of attitude is consistent with studies on adherence to other long-term therapies where the rationale for treatment extends beyond acute symptom relief. For example, research on antiretroviral therapy for HIV has often found that a patient's personal beliefs about the necessity and efficacy of the medication (attitude) are more powerful predictors of adherence than social support. Similarly, in tuberculosis treatment, a patient's belief in the cure and their positive outlook on the lengthy treatment regimen are critical for completion. Conversely, our findings contrast with studies where PBC is a dominant factor, such as in lifestyle changes like diet and exercise, where practical barriers, including time, cost, and access, can be substantial.[19] The context-dependent nature of the TPB's predictive power is one of its core strengths, and our study robustly demonstrates that for primaquine adherence in this Papuan cohort, the decisive battle appears to be won or lost in the mind of the patient.

The findings of this research have clear and direct implications for malaria elimination programs. The singular importance of attitude as a predictor of adherence intention demands a strategic shift towards more sophisticated, patient-centered communication that prioritizes building understanding and conviction. Standard health messages often focus on instructions like "Take one pill daily for 14 days." Our results suggest this should be supplemented or replaced with messages focused on the rationale, such as "This medicine kills the sleeping parasites in your liver to stop malaria from coming back and to protect your family". Educational materials should use simple, culturally resonant analogies and visual aids to explain the abstract concept of hypnozoites and the specific role of primaquine in achieving a "deep cure"” Clinicians, nurses, and community health workers are the primary interface with patients. They should be trained to move beyond simple prescribing and become "attitude shapers." This involves taking the time to elicit a patient's existing beliefs, explain the personal benefits of completing treatment, which might include preventing debilitating relapses and enabling consistent work or school attendance, and framing adherence as an act of personal empowerment over the disease.

While our study highlights the primacy of attitude, it does not advocate for the abandonment of other support systems. A robust public health strategy should be integrative. Community and family support (related to subjective norms) can be leveraged not just to enforce adherence, but to reinforce the positive messages about the importance of radical cure.[20] Logistical support (related to PBC) remains essential. Our findings suggest these efforts will be most effective when they are in service of a patient who has a strong, positive attitude and is therefore motivated to utilize the support available to them. The approach should be to enhance existing community and health system structures with powerful, attitude-focused communication.

This study has several notable strengths. It is one of the first to apply the full TPB framework to the specific problem of primaquine adherence in the hyperendemic context of Papua, Indonesia. The use of a validated theoretical model, a culturally adapted instrument, and robust statistical methods (penalized regression) to handle data complexities are significant methodological strengths. However, the findings must be interpreted in light of several limitations. First, the cross-sectional design demonstrates strong associations but cannot establish causality. A longitudinal study would be needed to show that changes in attitude lead to changes in intention and

behavior over time. Second, the study measured behavioral intention, not actual adherence. While intention is a strong predictor, a well-documented "intention-behavior gap" exists. Future research should incorporate objective measures of adherence, such as pill counts or biomarker analysis, to validate these findings.

Third, and most significantly, the study sample had several characteristics that limit the generalizability of the findings. The exclusion of patients with known G6PD deficiency means our results cannot speak to the adherence challenges in this important sub-population, for whom fear of side effects would likely create very different attitudinal and control beliefs. Furthermore, the sample was disproportionately highly educated compared to the general population of the region, which may have led to the observed ceiling effects in attitude and intention and an underestimation of the role of practical barriers. The findings may not be representative of more rural or less educated populations who bear a heavy burden of malaria. Finally, despite efforts to ensure confidentiality, the self-reported data may be subject to social desirability bias.

5. Conclusion

This study provides compelling, statistically robust evidence that in the fight against *Plasmodium vivax* malaria in Papua, Indonesia, the patient's own attitude towards treatment is a profoundly important determinant of their intention to achieve a radical cure. Our analysis, grounded in the Theory of Planned Behavior and corrected for statistical complexities, demonstrates that a patient's positive evaluation of the 14-day primaquine regimen is the most significant predictor of their commitment to therapy, surpassing the influence of perceived social pressures and practical barriers in this cohort. This finding carries a clear message for public health policymakers: to win the war against vivax malaria relapse, we must win the hearts and minds of patients. The path to malaria elimination in this region is not paved with instructions alone, but with understanding. Interventions must evolve from passive drug distribution to active, empathetic, and scientifically-informed communication strategies designed to build an unshakeable belief in the necessity and benefit of completing the full course of treatment. By enhancing current public health efforts with a focused strategy to cultivate this positive attitude, we can empower patients to become the most critical agents in their own healing and the ultimate drivers of community-wide malaria elimination. Further research is urgently needed to validate these findings in more diverse and representative populations.

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