

Review of *Plasmodium vivax* Malaria in Indonesia and Malaysia: Epidemiology of The Infection and The Presence of The Vector Across Time

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Abstract

Background: *Plasmodium vivax* causes malaria is a major public health concern in Southeast Asia, particularly in Indonesia and Malaysia. *Anopheles punctulatus*, a common vector, transmits the disease via the bite of infected female Anopheles mosquitos. Understanding the epidemiology and entomology of vivax malaria is critical for developing successful control and prevention strategies.

Materials and methods: This study investigates the epidemiology and entomology of *Plasmodium vivax* malaria in Indonesia and Malaysia over a period of time.

Results: Malaria research in Indonesia and Malaysia can provide insights into the parasite's genetic diversity and help tailor interventions to specific challenges. Findings from this review will contribute to global efforts to eradicate malaria and mitigate its effects on vulnerable populations. *Plasmodium vivax* malaria, which is prevalent in Indonesia and Malaysia, has been extensively studied by researchers. Variations in transmission dynamics and entomological factors have had an impact on the disease's spread and persistence. The emergence of *P. knowlesi* as a common cause of malaria in Malaysia demonstrates the intricate interplay between human behaviour and environmental factors.

Conclusion/Recommendations: The results of artesunate-mefloquine and artemisinin-based combination therapy demonstrate the importance of effective antimalarial regimens. *P. vivax's* unique genetic diversity and potential for out breeding highlight the importance of tailored interventions. More research is needed to better understand disease transmission dynamics and develop targeted interventions.

Keywords: *Plasmodium vivax* Malaria, epidemiology, entomology, human behaviour, environmental factor

Introduction

Malaria is one of the many infectious diseases caused by plasmodium through the bite of the female Anopheles mosquito. The breeding grounds for these mosquitoes are usually in puddles of fresh or salt water, rice fields, river estuaries where the flow is not heavy and small ponds containing rainwater.¹ Plasmodium is one of the many contributors to morbidity and mortality among the 2.85 billion people living at risk of infection. The geographical distribution is very wide, ranging from areas with cold, subtropical, to tropical climates.²

In the tropical regions of Indonesia and Malaysia, *Plasmodium vivax* Malaria has been a persistent public health concern for centuries. The introduction of this essay aims to provide a comprehensive examination of the epidemiology and entomology of this specific type of malaria across time in these two countries. By analyzing historical records, recent epidemiological studies, and entomological data, this research seeks to uncover trends, patterns, and potential explanations for the prevalence and transmission dynamics of *P. vivax* Malaria in the region. Through a multidisciplinary approach, we aim to shed light on the factors influencing the spread of this disease, such as climate change, human movement, and vector behavior. Ultimately, this study seeks to contribute to the body of knowledge on malaria control and prevention strategies in Indonesia and Malaysia.

Plasmodium vivax malaria, caused by the parasite *Plasmodium vivax*, is a significant public health concern in many regions of the world, including Indonesia and Malaysia. This type of malaria is

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characterized by recurrent fever episodes, which can be challenging to distinguish from other types of malaria. The transmission of *P. vivax* malaria is primarily through the bite of infected female Anopheles mosquitoes, with Anopheles punctulatus being a common vector in Southeast Asia. Historically, Southeast Asia has been a hotspot for vivax malaria due to factors such as climate, land use changes, and population movements. Understanding the background and epidemiology of *P. vivax* malaria in Indonesia and Malaysia is crucial for effective control and prevention strategies to combat this disease. Research studies have shown that variations in transmission dynamics and entomological factors have influenced the spread and persistence of *P. vivax* in these regions over time.³

It is paramount to examine the significance of studying Malaria in Indonesia and Malaysia due to the substantial burden this disease places on both countries. Malaria, caused by the Plasmodium parasite, continues to be a public health concern in these regions, with a high incidence of cases reported annually. By understanding the epidemiology and entomology of *Plasmodium vivax* Malaria in Indonesia and Malaysia, researchers can identify factors contributing to the transmission of the disease, develop effective prevention strategies, and enhance current control measures. Furthermore, studying Malaria in these countries can provide valuable insights into the genetic diversity of the parasite and help tailor interventions to address specific challenges faced in the region. Ultimately, this research can contribute to the global efforts in eradicating Malaria and reducing its impact on vulnerable populations.⁴

Understanding the research objectives is crucial in framing the study design and guiding the investigation into *Plasmodium vivax* Malaria in Indonesia and Malaysia. The primary aim of this research is to explore the epidemiology of *P. vivax* malaria in these regions, with a focus on understanding the trends in prevalence over time. By analyzing demographic data, such as age, gender, and geographical distribution of cases, we aim to identify high-risk populations and areas for targeted intervention strategies. Furthermore, the entomological aspects of *P. vivax* transmission will also be investigated to enhance our understanding of vector behaviour and its role in disease spread. Through a comprehensive investigation of both epidemiological and entomological factors, this study seeks to contribute valuable insights into the dynamics of *P. vivax* malaria in Indonesia and Malaysia, ultimately informing more effective control measures in the future.⁵

The scope of this study will focus on tracing the epidemiology and entomology of *Plasmodium vivax*

Malaria in Indonesia and Malaysia over a specified period of time. By examining historical data, trends, and patterns related to this specific type of malaria, we aim to shed light on the factors contributing to its prevalence and transmission dynamics in these two countries. This extensive analysis will provide insights into the impact of environmental, social, and geographical factors on the spread of the disease, as well as the effectiveness of control measures implemented over time. By delving into the past and present of *Plasmodium vivax* Malaria in Indonesia and Malaysia, this study seeks to contribute valuable information to the existing body of knowledge on malaria epidemiology and entomology. Through a comprehensive examination of relevant literature and data sources, we aim to provide a holistic understanding of the complexities surrounding this specific type of malaria in these regions.⁵

Furthermore, this paper aims to investigate the epidemiology and entomology of *Plasmodium vivax* malaria in Indonesia and Malaysia across different time periods. By analyzing historical and present data on malaria cases, vector abundance, and control strategies, this study seeks to identify any trends or patterns that may have emerged over time. The paper also explore the impact of environmental changes, human behavior, and public health interventions on the transmission dynamics of *P. vivax* malaria in these two countries. By synthesizing past research findings with current data, this study intends to contribute to a better understanding of the factors influencing the spread of *P. vivax* malaria in Southeast Asia and provide insights for future prevention and control efforts.

Materials and methods

This research was based on a literature review. Online literature searches were conducted in Science Direct, Scopus databases, and Google Scholar. Search strategies included the following keywords: *plasmodium vivax*, malaria, Indonesia, Malaysia, epidemiology, entomology. Searches were conducted in English, with no limitations on the year of publication.

Epidemiology of *Plasmodium Vivax* Malaria

Plasmodium vivax is estimated to contribute to about 14 million cases of malaria each year.⁶ High cases of illness and death are often associated with vivax malaria. However, in some endemic areas, diagnosis, prevention, treatment, and control are not optimal. Malaria vivax was once thought of as a benign infection, but it can now cause severe pain in a variety of epidemiological settings. This parasite can cause widespread indirect death due to recurrent infections and the cumulative risk of severe anemia.⁷

The number of malaria cases in Indonesia over the past few years has increased. The Indonesian Ministry of Health said that in the 2020-2022 period, there were at least 443,530 cases. The Eastern Indonesia region dominated around 400,252 cases in 2022, of which Papua Province contributed 356,889 cases from the national figure.⁸ On the other hand, WHO reported that malaria in Malaysia from 2015-2021 reached 23,214 cases, of which 87% were zoonoses. Parasites of the genus *Plasmodium* are the cause of this disease. Not only dangerous to humans, plasmodium also endangers birds, reptiles, mammals, and other species of vertebrates.⁹

In East Kutai Regency, Indonesia, a study revealed key insights into the profile of malaria infections, highlighting a predominance of cases in males aged 25 to 34 years with high forest contact, predominantly caused by *P. vivax*.¹⁰ Additionally, genetic epidemiology studies in Papua, Indonesia, underscored long-term changes in *P. vivax* populations, showing a decrease in polyclonal infections over time and the persistence of strains for up to 9 years, indicative of higher rates of outbreeding in *P. vivax* compared to *P. falciparum*. The findings emphasize the importance of understanding genetic diversity and transmission dynamics in shaping malaria control strategies, particularly in regions with endemic *P. vivax* transmission like Indonesia and Malaysia.¹¹

Historical Overview of Malaria in Indonesia and Malaysia

Malaria has significantly impacted Indonesia and Malaysia for centuries, with frequent outbreaks leading to high morbidity and mortality rates. Various control measures, including insecticides, bed nets, and prophylactic drugs, have been implemented, but challenges persist, especially in rural areas with limited healthcare access. Despite ongoing efforts, malaria remains a major public health concern. By analyzing past experiences, policymakers and healthcare professionals can develop more effective strategies to combat *Plasmodium vivax* malaria in the region.³

Historical records show that Dutch traders arrived in Indonesia in the late 16th century and colonized the region for two centuries. Early documents suggest that a fever, likely malaria, affected traders. Since the central government and VOC administration were based in Java, most early malaria reports originated there. By the 18th century, Batavia (Jakarta) experienced severe malaria outbreaks, causing high morbidity and the deaths of thousands of VOC employees annually.¹²

Current Epidemiological Data

The number of malaria cases in Indonesia over the past few years has increased. The Indonesian Ministry of

Health said that in the 2020-2022 period, there were at least 443,530 cases. The Eastern Indonesia region has a population of around 400,252 cases in 2022, of which Papua Province contributes 356,889 cases from the national figure.⁸ Between 2015 and 2021, Malaysia recorded 23,214 malaria cases, with 87% classified as zoonotic, according to WHO. The disease is caused by *Plasmodium* parasites, which not only threaten humans but also birds, reptiles, mammals, and other vertebrates.⁹ Meanwhile, the majority of malaria cases caused by *Plasmodium vivax* in Malaysia were in Peninsular Malaysia during 2013-2017. The average mortality rate due to this species was the lowest compared to *Plasmodium falciparum* and *Plasmodium knowlesi*.¹³

In Malaysia, the recurrence rate is 836 cases per 10,000 people per day. This phenomenon is predicted due to climate change, mode of transmission, and vector conditions. The socioeconomic impact of this disease also contributes to a country. If it is not monitored regularly, it will affect development in the country.¹⁴ Many studies have revealed that *P. Vivax* is more difficult to remove than *P. falciparum* because of the characteristic unconscious recurrence characteristic or hypnozoites.¹⁵

The analysis of imported malaria data helps shape prevention strategies in malaria-free regions. A study¹⁶ highlights the ongoing risk in China, with most *Plasmodium falciparum* cases originating from Western Africa. It emphasizes the need for targeted health education and improved surveillance in county-level medical institutions. Moreover, the findings by¹⁷ emphasize the utility of methaemoglobin levels as a surrogate endpoint for assessing the efficacy of 8-aminoquinoline drugs in preventing *P. vivax* recurrence. The study of imported malaria trends aids in developing prevention strategies for malaria-free regions. In China, most *Plasmodium falciparum* cases come from Western Africa, highlighting the need for targeted health education and enhanced surveillance at local medical institutions.

Factors Contributing to Malaria Transmission

Various factors contribute to the transmission of malaria, particularly in regions like Indonesia and Malaysia. One key factor is the prevalence of suitable mosquito vectors, such as *Anopheles* mosquitoes, which are efficient carriers of the *Plasmodium* parasite. These vectors thrive in tropical climates with high humidity and abundant standing water. Additionally, human activities, such as deforestation and urbanization, can create more habitats for mosquitoes to breed, increasing the risk of transmission. Socioeconomic factors, such as poor access to healthcare and inadequate vector control measures,

also play a significant role in the spread of malaria in these regions.⁵

Some areas of Lampung Province, Indonesia have become malaria endemic areas due to environmental factors in the farm where there are many swamps, brackish waterlogging by the seaside, and fish ponds that are not maintained. This condition can certainly be a habitat for *Anopheles sp* mosquitoes.¹⁸ Kalimantan, covering much of the island's southern region and bordering Malaysian Borneo, has historically been a hotspot for *Plasmodium falciparum* and *Plasmodium vivax* transmission, contributing to malaria spread in Malaysia. In recent decades, deforestation of one-third of Kalimantan's forests has led to urbanization, wildlife migration near settlements, and climate changes, all of which have intensified malaria transmission.¹²

Demographic factors, particularly population density, can influence malaria transmission. People returning from vacations or work in endemic areas are vulnerable to infection through *Anopheles* mosquito bites. *Plasmodium vivax* presents an even greater challenge, as it can remain dormant in the liver for extended periods, causing recurrent infections. This persistence highlights the need for timely diagnosis and proper treatment to prevent further spread and complications.¹⁹ Malaria has been a priority public health burden in Eastern Indonesia since 2005-2010 based on a report by the local Health Office.²⁰ Understanding and addressing these contributing factors is critical to effectively combating malaria transmission and reducing the burden of disease in Indonesia and Malaysia.

Impact of Climate Change on Malaria Distribution

P. vivax transmission relies on the presence of mosquito vectors, their bite rate, and parasite development. However, these factors are heavily influenced by climatic conditions, such as temperature, humidity, and rainfall, which affect mosquito breeding and parasite maturation, ultimately impacting malaria spread.²¹ Recent studies indicate that climate change is altering the distribution of malaria-carrying mosquitoes. In endemic regions like Indonesia and Malaysia, rising temperatures and shifting precipitation patterns have created ideal breeding conditions, increasing malaria cases. Additionally, warming temperatures have allowed mosquitoes to expand into higher altitudes, exposing new populations to the disease and complicating control efforts. Understanding the relationship between climate change and malaria transmission is essential for developing effective interventions and policies to mitigate its impact.²² Global climate change, encompassing temperature, humidity, light, rainfall, and wind patterns, directly affects mosquito reproduction and parasite

development. Low humidity shortens mosquito lifespan, but it can still influence parasite survival and transmission dynamics, impacting malaria spread.²³ The western and central regions of Indonesia have warm temperatures that facilitate the multiplication of *P. falciparum* and *P. vivax*. In contrast, the eastern region, characterized by numerous high mountains, has a more humid and cooler climate. This lower temperature differentiates it from other parts of Indonesia and may influence malaria transmission dynamics.²⁴

Control and Prevention Strategies

Vector control measures such as indoor residual spraying, insecticide-treated bed nets, and larval control have been successful in reducing malaria transmission. Additionally, early diagnosis and prompt treatment with effective antimalarial drugs are essential for preventing severe complications and interrupting the transmission cycle.²⁵ Community engagement and education are crucial in promoting preventive behaviors and encouraging timely healthcare-seeking. Continuous surveillance of malaria cases, vector populations, and drug resistance is essential for adapting interventions and assessing their effectiveness. A comprehensive approach that integrates vector control, case management, and active community participation is key to achieving sustainable progress in controlling and eliminating *Plasmodium vivax* malaria in the region.

Entomology of Plasmodium Vivax Malaria

According to WHO and the Indonesian Ministry of Health, *P. vivax* only infects young erythrocytes, resulting in a lower parasite density in the blood. However, its ability to enter a hypnozoite phase allows the parasite to remain dormant in the liver, leading to relapses or recurrences. This makes detection and eradication challenging, requiring targeted treatment strategies.²⁶ In Indonesia and Malaysia, *Anopheles maculatus* and *Anopheles aconitus* are primary vectors of *P. vivax* malaria. Their differing blood-feeding and resting behaviors influence disease transmission and distribution. Understanding their biology and ecology is essential for developing effective vector control strategies. Additionally, research on insecticide resistance in *Anopheles* populations highlights the need for innovative approaches to combat *P. vivax* malaria in endemic regions.³ By integrating entomological data into malaria control programs, we can ultimately work towards eliminating this disease in Indonesia and Malaysia.

Anopheles Mosquito Vectors in Indonesia and Malaysia

In understanding the dynamics of *Anopheles* mosquito vectors in Indonesia and Malaysia, essential insights

from recent studies shed light on the genetic diversity and potential implications for malaria transmission. The research in Benin highlighted the presence of non-falciparum species contributing to malaria cases, emphasizing the significance of identifying various *Plasmodium* species for effective control programs²⁷.

Similarly, investigations in Malaysia revealed distinct genetic clusters within *Anopheles latens*, possibly indicating cryptic species, while other vectors showed varying levels of genetic polymorphism and demographic expansion, hinting at population growth and range expansion²⁸. These findings underscore the complex interplay between vector genetics and malaria transmission, emphasizing the need for comprehensive entomological studies to inform targeted interventions and surveillance strategies in the context of *Plasmodium vivax* malaria in Indonesia and Malaysia.

Vector Biology and Behaviour

Mosquito biting behaviour (bionomics), bite rate, and reproduction are influenced by temperature changes. Higher temperatures accelerate mosquito breeding cycles and shorten the maturation period of the parasite within the vector, leading to increased malaria transmission risks.²⁹ Understanding vector biology and behavior is essential in studying *Plasmodium vivax* malaria. *Anopheles* mosquitoes, as primary vectors, influence transmission through their breeding habits, host-seeking patterns, and biting behavior. Factors such as vector density, insecticide resistance, and environmental conditions further affect disease spread. Additionally, human activities and interactions with vectors add complexity to malaria transmission, highlighting the need for targeted research and control strategies.⁵ Studying the biology and behavior of *Anopheles* mosquitoes allows researchers to develop more effective vector control and malaria prevention strategies. This is particularly crucial in Indonesia and Malaysia, where malaria remains a major public health challenge. Understanding mosquito habits can help tailor interventions to reduce transmission and improve disease management in endemic regions.

Vector Control Measures

Effective vector control is crucial in combating malaria, using strategies like insecticide-treated bed nets, indoor spraying, larval control, and environmental management. In Indonesia and Malaysia, these efforts have significantly reduced *Plasmodium vivax* transmission by targeting *Anopheles* mosquitoes. Continuous research and monitoring are essential to adapt strategies and integrate new technologies, making malaria elimination more achievable.²⁵

The Purworejo Regency Health Office and Indonesia's

Ministry of Health control malaria through migration surveillance, patient treatment, insecticide-treated nets, and indoor residual spraying (IRS). Effective control requires detailed knowledge of methods, timing, targets, locations, and insecticide concentrations. Understanding vector species, behavior, and bionomics is also a priority to enhance efficiency.³⁰

Insecticide Resistance in Anopheles Mosquitoes

The WHO in 2016 stated that *Anopheles* mosquitoes have resistance to exposure to standard doses of insecticides. Some types of insecticides used in households are Baygon®, Abate Powder, Hit®, Force magic® and Vape.³¹ Resistance of *Plasmodium falciparum* and *Plasmodium vivax* to antimalarial drugs has been observed in Southeast Asia, with imported malaria contributing to the risk in Malaysia. Monitoring and preventing the spread of drug-resistant strains are crucial for achieving malaria elimination.³²

Insecticide resistance in *Anopheles* mosquitoes challenges malaria control in Indonesia and Malaysia. Resistance mechanisms, including target-site mutations and metabolic detoxification, reduce the effectiveness of indoor residual spraying and insecticide-treated nets, sustaining malaria transmission. Future efforts should focus on developing new insecticides, rotating different insecticide classes, and implementing integrated vector management to combat resistance.⁵ By addressing insecticide resistance comprehensively, sustainable progress can be made in reducing the burden of *Plasmodium vivax* malaria in Indonesia and Malaysia.

Research Advances in Vector Control

Recent research studies in East Kutai Regency, Indonesia¹⁰ and South Kalimantan³³ have shed light on the critical factors influencing malaria prevalence, particularly in forest areas. Understanding malaria epidemiology, including age, sex, and occupation patterns, is key to effective vector control. High-risk groups, such as males aged 25–34 with forest exposure, require targeted interventions. Identifying *Plasmodium* species, like *P. vivax*, helps tailor control strategies. Ongoing research in vector control remains crucial for combating malaria in endemic regions.

Africa has made significant advances in vector control through rapid diagnosis, mosquito net promotion, insecticides, intermittent preventive therapy (IPT), chemo-prevention for high-risk groups, and artemisinin-based combination therapy (ACT) for malaria treatment. These efforts, supported by ongoing drug research and WHO assistance, have proven effective in reducing malaria cases.³¹ Similar efforts can be adopted by Indonesia and Malaysia against the

Anopheles mosquito vector from the *Plasmodium vivax* population.

Comparative Analysis Across Time

A comparative analysis of *Plasmodium vivax* malaria in Indonesia and Malaysia highlights the evolving epidemiology and entomology of the disease. Technological advancements and research have enhanced understanding of transmission patterns and parasite diversity. By examining historical data alongside current trends, researchers can identify key factors shaping malaria dynamics, including climate change, urbanization, and human mobility.⁵ This comparative approach allows for a more holistic view of the disease burden in both countries, paving the way for targeted interventions and control strategies to effectively combat the spread of malaria.

A 2002 study found that despite a decline in the annual parasite incidence (API) in Central Java, some areas remain difficult to control, including the Menoreh Mountains. Spanning Purworejo and Magelang Regencies (Central Java) and Kulon Progo Regency (DI Yogyakarta), this cross-border region remains a persistent malaria hotspot. It was the first area in Java to be designated as a major endemic zone. A 2019 spatial analysis revealed that the primary malaria cluster was in Purworejo Regency, with secondary clusters in neighboring districts.³⁴

Changes in Malaria Incidence Rates Over Time

In examining the dynamics of *Plasmodium vivax* malaria incidence rates over time in Indonesia and Malaysia, it is crucial to consider the diverse factors influencing malaria transmission and control strategies. According to³⁵ the persistence of submicroscopic infections and hypnozoite reservoirs poses challenges to standard control measures, leading to the ongoing transmission of *P. vivax* in complex local settings. Furthermore,³⁶ highlights the global efforts towards malaria elimination and eradication, emphasizing the importance of strong surveillance systems, entomological interventions, and evidence-based strategies in achieving successful outcomes. Examining national malaria programs in countries like Sri Lanka and Bhutan provides valuable insights into malaria elimination efforts. Their successes and challenges offer a framework for analyzing changes in malaria incidence over time, considering evolving prevention and control strategies.

Evolution of Malaria Parasites and Vectors

Malaria parasites, such as *Plasmodium vivax*, have adapted to survive and multiply within their human hosts, while also evolving mechanisms to evade the immune system and develop resistance to antimalarial drugs. Concurrently, mosquito vectors like *Anopheles*

species have co-evolved with the parasites, developing strategies to efficiently transmit the pathogens from one host to another. The genetic diversity of malaria parasites and vectors influences their ability to adapt to changing environmental conditions, host immune responses, and vector control measures. By elucidating the evolutionary history of malaria parasites and vectors, we can gain insights into the complex interactions driving the spread of the disease and inform public health interventions to mitigate its impact on vulnerable populations.³ The incubation period of the malaria parasite *Plasmodium vivax* intrinsically begins from the entry of the parasite into the human body until clinical symptoms appear, which is for 12-17 days.³⁷

Public Health Interventions and Their Effectiveness

These public health interventions play a crucial role in controlling the spread of the disease and reducing its impact on the local populations. Various strategies such as vector control, early diagnosis, and treatment, as well as community engagement and education have been utilized to combat the transmission of the malaria parasite. Studies have shown that targeted interventions can significantly reduce the burden of *P. vivax* malaria in endemic regions, leading to a decline in morbidity and mortality rates. However, the effectiveness of these interventions can vary depending on the local context, environmental factors, and socioeconomic conditions. Therefore, continuous evaluation and adaptation of public health strategies are essential to ensure their success in fighting against malaria.²⁵

Each intervention has its own advantages in malaria control. A multisectoral and multidimensional approach using 4 interventions, namely insecticide treated nets (ITN), long-lasting insecticidal nets (LLINs), and indoor residual spraying (IRS), and mass media campaigns are urgently needed. In many countries, the use of multiple malaria interventions simultaneously is more effective at preventing mosquito bites and controlling vector populations than using a single intervention alone.³⁸

Lessons Learned for Future Malaria Control Programs

Firstly, the importance of community engagement cannot be overstated. Active involvement and empowerment of local communities are crucial for the success of control efforts. Secondly, integrating multiple control measures, such as vector control, early diagnosis, and prompt treatment, is essential for effectively reducing malaria transmission. Lastly, continuous monitoring and evaluation of control programs are necessary to assess their impact and make

necessary adjustments. By incorporating these lessons into future malaria control programs, we can strive towards sustainable and long-term success in reducing the burden of *Plasmodium vivax* malaria in Indonesia and Malaysia.

Discussion

Plasmodium vivax is a malaria parasite whose populations are found in Latin America, Asia, and the South Pacific. The formation of diversity and population structure across continents is influenced by multiple factors. For example, the intensity of transmission is lower in South America than in Southeast Asia and the South Pacific, or the geographical isolation of this parasite in the South Pacific. A study of 841 isolates from South and Central America, Africa, Central Asia, Southeast Asia, and the South Pacific revealed that the highest diversity occurred in Southeast Asia. Places of transmission include the medium-high category and the migration of humans (hosts) to be highly infected. Meanwhile, South America and Central Asia are the lowest and localized places of malaria spread.³⁹

Blood stage infections due to *Plasmodium vivax* tend to have a lower density than *P. falciparum* so the diagnosis is often missed. Hypnozoites carried by Plasmodium Vivax can cause recurrence after some time of exposure to primary infections and increase the potential for new transmission. Unfortunately, the diagnostic tools currently available are not capable of detecting when an inactive liver wakes up and triggers some episodes of malaria vivax. This causes some infected people to be unaware of it. Such conditions are a challenge for malaria control and elimination programs because of the difficulty of detecting malariometric surveys or active case detection campaigns.⁴⁰

Since 1998, malaria has become one of the list of diseases that must be reported in Malaysia. All laboratory-confirmed cases must be reported to the nearest district health office within 7 days of being confirmed before sending data to the central level¹³ The epidemiological studies conducted in Malaysia and French Guiana have yielded significant insights into the transmission and clinical manifestations of *Plasmodium vivax* malaria. In Malaysia, the emergence of *P. knowlesi* as a common cause of malaria, particularly among farmers and individuals engaged in specific activities at the forest edge, highlights the complex interplay between human behavior and environmental factors in disease transmission.⁴¹ Additionally, the successful treatment outcomes of artesunate-mefloquine compared to chloroquine underscore the importance of effective antimalarial regimens in managing *P. knowlesi* infections. In French Guiana, the outbreaks among military personnel engaged in illegal gold mining activities in remote

rainforest areas demonstrate the challenges of controlling malaria in hyperendemic settings where competent vectors like Anopheles mosquitoes play a pivotal role in disease transmission.⁴² These findings emphasize the need for tailored strategies to address malaria transmission in diverse ecological and human contexts, guiding future efforts towards comprehensive malaria control and elimination programs in these regions.

The evolving genetic diversity and transmission patterns of *Plasmodium falciparum* and *P. vivax* populations in co-endemic regions present crucial considerations for public health policies¹¹ The observed decrease in polyclonal infections over time, particularly in *P. falciparum*, signifies a potential reduction in transmission rates following the implementation of Artemisinin-based Combination Therapy (ACT). Furthermore, the distinct genetic structures of the two species, with *P. vivax* displaying higher rates of outbreeding, emphasize the need for tailored interventions to disrupt transmission effectively. Additionally, the recognition of *P. vivax* as a significant threat associated with severe illness and potential mortality reinforces the urgency for comprehensive public health strategies that address the unique challenges posed by this parasite, including the management of hypnozoites and safe administration of primaquine therapy.⁴³ Public health policies must therefore account for the complex epidemiological dynamics and clinical implications highlighted by these findings to mitigate the burden of vivax malaria effectively.

In 2022, WHO stipulates certification as an elimination requirement. of zoonotic malaria parasite species (e.g. macaque long-tailed monkey). This makes Malaysia the first country not to receive malaria elimination certification because malaria species other than *P. Vivax* were found to be zoonotic. This condition raises big questions regarding the feasibility of malaria elimination in other countries that have also reported zoonotic malaria cases.⁴⁴ A study revealed that the success of malaria prevention and control programs can be seen from the behaviour of the community itself. Maintaining environmental cleanliness, using insecticide mosquito nets, mosquito repellents, and installing wire mesh at home⁴⁵

Moving forward, there are several key areas that warrant further investigation in order to enhance our understanding of *Plasmodium vivax* malaria in Indonesia and Malaysia. Firstly, future research should focus on exploring the potential impact of climate change on the distribution and transmission of this disease, as changes in temperature and precipitation patterns may influence the prevalence of the Anopheles mosquitoes responsible for transmitting the parasite.

Additionally, more studies are needed to examine the effectiveness of current control measures, such as vector control strategies and antimalarial drug regimens, in the context of evolving drug resistance and insecticide resistance. Furthermore, investigations into the genetic diversity of *Plasmodium vivax* strains circulating in these regions could provide valuable insights into the parasites transmission dynamics and inform the development of more targeted interventions. Collaboration between researchers, public health officials, and local communities will be essential to address these research gaps and ultimately work towards the goal of malaria elimination in Indonesia and Malaysia.⁴⁶

The high number of vivax malaria cases found in several studies is a code for the government to prioritize these cases. Malaria prevention and control campaigns can be carried out to increase public awareness so that its prevalence decreases and is eliminated gradually.⁴⁷ Since 2018, the national malaria elimination and eradication program has been effective enough to produce zero cases in the indigenous population. However, the high level of malaria exposure and its transmission pattern in the population needs to be a concern. The epidemiological transition of malaria cases from moderate to low is a challenge for each country to assess the performance of intervention programs and the impact of their evaluation. In order to consolidate profits and advance malaria elimination, better tools are needed to monitor infections on a regular basis.⁴⁸ Until now, efforts to control *P. Vivax* maraia are still limited by the lack of effective radical cure options.⁴⁹

One major limitation of this study is the reliance on secondary data sources, which may introduce potential biases or inaccuracies in the findings. While efforts were made to validate the data through cross-referencing and verification, there is still a possibility of errors in the original data collection processes. Another limitation is the scope of the study, which focused primarily on *Plasmodium vivax* malaria in Indonesia and Malaysia. This narrow geographic focus may limit the generalizability of the findings to other regions or countries facing similar challenges. Additionally, the study predominantly examined epidemiological and entomological aspects, leaving out other potential factors that could influence the transmission and control of malaria. Future research could benefit from expanding the scope to include a more comprehensive analysis of social, economic, and environmental factors that contribute to the prevalence of *Plasmodium vivax* malaria in Southeast Asia⁵⁰

Conclusion

The epidemiology and entomology of *Plasmodium vivax* Malaria in Indonesia and Malaysia have shown a

complex interplay of factors contributing to the transmission and prevalence of this disease over time. The historical data analyzed in this study reveal patterns of outbreaks and declines, influenced by various environmental, social, and biological factors. Despite efforts to control malaria through vector control programs and healthcare interventions, the persistence of *P. vivax* in these regions remains a significant challenge. Moving forward, continued research and surveillance are essential to understand the changing dynamics of malaria transmission and to develop effective strategies for prevention and control. By addressing the gaps in current knowledge and incorporating a multidisciplinary approach, we can work towards reducing the burden of *P. vivax* Malaria in Indonesia and Malaysia. In conclusion, the study of *Plasmodium vivax* Malaria in Indonesia and Malaysia has shed light on the complex interplay between epidemiology and entomology over time. Understanding the transmission dynamics and prevalence of this parasite is crucial for effective control and preventative measures. By examining historical trends and current data, researchers can better pinpoint areas of high risk and tailor interventions to combat the spread of the disease. While progress has been made in terms of treatment and prevention, challenges still remain, particularly in regions with limited resources and access to healthcare. Continued research and collaboration between scientists, governments, and local communities will be essential in the ongoing battle against *P. vivax* Malaria. It is imperative that efforts to control this disease are sustained and adapted to the changing landscape of malaria transmission in these regions. In Indonesia and Malaysia, *Plasmodium vivax* malaria is a significant issue, requiring further research to understand its distribution, resistance, and genetic diversity, as well as the effectiveness of current control measures.

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