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Malaria Cases in Jayapura District, Mimika District, and Jayapura City, Papua 2023

Nisa Fauziah[1,2,3,4,5]✉, Leonard H. Jososudarmo[6], Budi Sujatmiko[7], Naufal Fakhri Nugraha[2,4,7], Jontari Hutagalung[8]

[1]Department of Biomedical Sciences, Faculty of Medicine, Universitas Padjadjaran, Indonesia
[2]Research Center for Care and Control of Infectious Diseases (RC3ID) Universitas Padjadjaran, Indonesia
[3]Parasitology Laboratory of Human, Safety and Environment (HSE), Universitas Padjadjaran, Indonesia
[4]Universitas Padjadjaran Hospital, Indonesia
[5]Doctoral Program, Faculty of Medicine, Universitas Padjadjaran, Indonesia
[6]Graduate Medical Study Program, Faculty of Medicine, Universitas Padjadjaran, Indonesia
[7]Department of Public Health, Faculty of Medicine, Universitas Padjadjaran, Indonesia
[8]Laboratory of Parasitology, Center for Health Resilience System Policy and Health Resources, Health Policy and Development Agency, Ministry of Health, Indonesia

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Abstract

Papua has been known as the area with the highest number of malaria cases in Indonesia; however, there has been a little shortage of studies on the distribution of malaria cases in the area. The lack of studies on the distribution and proportion of malaria cases in the Papua region, which can affect the surveillance of malaria, prompted this study to be conducted. This is a descriptive study with an explorative research design, observation approach on secondary data, and analysis with the help of Geographic Information System (GIS). The population of the study is all malaria patients recorded in 8 health facilities in Mimika District, Jayapura District, and Jayapura City between March and May 2023. The results showed that the total number of malaria patients is 128 people with various proportions of demographic aspects, including age, sex, ethnicity, duration of stay, and health care facilities. Proportion of malaria cases by the Plasmodium species, health care facilities distribution, and months recorded were also obtained, with the highest number of malaria cases caused by Plasmodium falciparum (44,53%), found in Mimika District, and according to healthcare facilities, it is Primary Health Care (PHC) Mimika, and found in March. It is also found that there is an increase in cases from March to May in Mimika District. Variations in case distribution can be caused by differences in geographical conditions, sanitary conditions of the area, the area's climate, ethnic proportion, people's activities, and risk factors.

Introduction

One of the infectious diseases that can infect the human body is malaria. This illness is caused by the *Plasmodium* sp. parasite and spread through mosquito vectors, specifically *Anopheles sp* (Nicoletti, 2020). Various types of *Plasmodium* parasites can infect humans, including *P. falciparum*, *P. vivax*, *P. malariae*, *P. ovale*, and *P. knowlesi*. After completing its sexual phase in the mosquito's body, the *Plasmodium* enters the human body when the mosquito feeds on blood and then develops asexually there (Castro, 2017; Protopopoff *et al*., 2009; Rejeki *et al*., 2021). *Plasmodium* parasites

✉ Correspondence Address:
Department of Biomedical Sciences, Faculty of Medicine, Universitas Padjadjaran, Indonesia;
Email: nisa@unpad.ac.id

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developing in the host's body can lead to initial symptoms that are nonspecific and mimic a flu-like illness. Individuals may experience fever, chills, sweating, headaches, or weakness. Fever is a key indicator for diagnosing malaria patients, typically starting irregularly at first and then escalating periodically based on the specific type of *Plasmodium* infection. Patients may also report muscle pain, anemia, and loss of consciousness, and if not treated properly, it can be fatal (Bartoloni & Zammarchi, 2012).

Malaria poses a significant global health challenge, particularly in tropical regions like Indonesia. A total of 247 million cases of malaria are reported in 84 endemic countries in the World Malaria Report 2022. The majority of these cases (96%) are contributed by 29 countries, with Nigeria being the largest contributor at 27%, followed by the Democratic Republic of Congo at 12%, Uganda at 5%, and Mozambique at 4%. While the number of malaria-related deaths worldwide decreased between 2000 and 2019, there was a roughly 10% increase in 2020, accounting for an estimated 619,000 deaths in 2021 (WHO, 2021). This increase is believed to be attributed to a health system response that was primarily focused on addressing the COVID-19 emergency rather than effectively controlling and preventing other diseases such as malaria (Gao *et al*., 2023; Liu *et al*., 2022). The Asian region is the second largest contributor to malaria cases (with the number of cases ranging from 5.4 million in 2021) after the African region (WHO, 2021). In the Asian region, Indonesia is in second place as the country with the most cases (15.6% of cases) after India at 82.5%, and the third place is occupied by Myanmar (1.6% of cases) (The Lancet Regional Health – Southeast Asia, 2022). Malaria cases in Indonesia in 2022 were 443530, with an API (Annual Parasite Incidence) of 1.61, indicating that it is a medium-endemic area, with cases being concentrated in the eastern part of Indonesia, namely the provinces of Papua, West Papua, and NTT. Papua is the region with the highest number of cases, 393,801 cases, with an API index of 89.1 in 2022. There are 29 districts/cities in Papua Province, with 19 of them having the status of High Malaria Endemic, 5 Medium Endemic, 5 Low Endemic, while there are two regency in which already been declared free from malaria, which are Sorong Selatan and Arfak Regency Mountains (Kemkes RI, 2022). Based on data from the Ministry of Health, the 3 districts/cities with the most positive malaria cases in Papua are Mimika with 77,379 cases, Jayapura City with 27,436 cases, and Jayapura Regency with 17,676 cases. The three areas that are high malaria endemic areas are the northern area (Jayapura Regency and City) and the southern area (Mimika Regency), and the two areas are 443 km apart.

Understanding the distribution of different types of *Plasmodium* that cause malaria infections is crucial for calculating disease burden, planning malaria case management, and making healthcare decisions (Ketema & Bassat, 2020; Landier *et al*., 2016; Patil *et al*., 2009; Stresman *et al*., 2020). Treatment for malaria varies depending on the specific type of *Plasmodium* involved, such as treating relapse cases in *Plasmodium vivax* or severe cases caused by *Plasmodium falciparum* (Battle *et al*., 2019). Among the Plasmodium species, infections due to P. falciparum and P. *vivax* are the most common, with 193.9 million and 14.3 million cases, respectively. In contrast, the prevalence of *Plasmodium malariae* and *ovale* infections is lower at 2.01% and 0.77%, respectively (Battle *et al*., 2019; Hawadak *et al*., 2021; Weiss *et al*., 2019). In Indonesia, *Plasmodium falciparum* and *vivax* account for the majority of malaria cases, with 50.55% and 34.18% respectively, while *Plasmodium malariae* and *ovale* infections make up only 2.07% and 0.06% of cases. The data also reveal co-infection between different Plasmodium species in Indonesia, accounting for 13.04% of all cases. Currently, there is a lack of data specifically addressing the distribution of *Plasmodium* species in the Eastern region of Indonesia, including Mimika District, Jayapura City, and Jayapura Regency, which is noteworthy considering their high number of malaria cases in Papua (Kemkes RI, 2022). Furthermore, the number of malaria cases in Papua has increased in the last five years (Kemkes RI, 2022). Known factors that contribute to the situation are mainly geographical conditions, high precipitation, *Anopheles* behaviour, human movement, limited malaria logistics, and the political situation in the area. Therefore the availability of detailed data outlining the malaria situation in a particular area can contribute to ongoing efforts for malaria control and surveillance (Aggarwal & Ranganathan, 2019; White *et al*., 2018). This is because insufficient malaria control and surveillance in an endemic area may affect the potential occurrence of imported malaria cases in regions that are already free from malaria (González-Sanz *et al*., 2023). Meanwhile, the latest research on the distribution study of malaria cases in the Papua region was conducted in Sentani Timur District, Jayapura Regency, in 2019 (Hastuty & Setyowati, 2021).

The paucity of studies, limited area, and duration of current studies on malaria case distribution in the Papua Region serve as the foundation for this study. This study will concentrate on the three regions in Indonesia that contribute the most malaria cases and are included in Papua's accelerated malaria elimination program, namely Jayapura Regency, Jayapura City, and Mimika Regency, using current data. As a result, it is hoped that an understanding of the distribution of malaria cases in Papua's three districts/cities will aid in the development of surveillance and control programs, as well as malaria-related research, thereby contributing to the national goal of eradicating malaria by 2030. The study aims to describe the demographic overview of malaria patients, distribution of malaria cases, and proportion of each *Plasmodium* type infections in three district-cities in Papua.

Method

This study employed a retrospective approach using medical records of malaria patients obtained from the Parasitology Laboratory of the Center for Health Resilience System Policy and Health Resources (Pusjak SKK and SDK). The dataset comprised information from 128 patients across three regions in Papua: Mimika District, Jayapura District, and Jayapura City, collected over three months from March to May 2023. Patient data were sourced from eight healthcare facilities: Primary Health Care (PHC) Koya Barat, PHC Harapan, PHC Hamadi, General Hospital Yowari, PHC Pasar Sentral, PHC Wania, PHC Karang Senang, and PHC Timika. To ensure data reliability and consistency, specific inclusion and exclusion criteria were applied. The inclusion criteria required that all selected records belonged to malaria patients with RT-PCR-confirmed diagnoses, resided within the three study regions, and had medical records within the designated timeframe. Records with missing or incomplete data were excluded. A rigorous data cleaning process was undertaken to eliminate inconsistencies and omissions before categorizing the dataset into key demographic and clinical variables, including age, sex, ethnicity, district/city of residence, duration of hospital stay, healthcare facility attended, and RT-PCR test results. Descriptive statistical analyses were conducted using Microsoft Excel for preliminary data processing and STATA 18 Special Edition for advanced statistical computations. Furthermore, geospatial analysis was performed to visualize the distribution of malaria cases and healthcare facilities. Secondary data containing the geographic coordinates of each facility were processed using Quantum GIS 3.38.0 RC, enabling the creation of spatial maps that illustrate the spread and clustering of malaria cases within the study regions. This methodological approach ensured a structured and comprehensive analysis of malaria cases across the selected districts and cities in Papua.

Result And Discussion

A total of 128 patients' data were grouped and distributed based on age, sex, ethnicity, duration of stay, area, health care facility, *Plasmodium* species, and according to the geographical information system. Demographic data from 8 registries of health care facilities in 3 districts and or cities of Papua from the period March to May 2023 are shown in Table 1. It was found that the most malaria patients from data from 3 districts and or cities in Papua in the period March to May 2023 were in Mimika Regency, with 64 cases. The number of cases in Jayapura district amounted to 43 cases, and Jayapura City amounted to 21 cases. The highest and lowest number of malaria cases among the 8 health facilities in the three study areas were in Jayapura district at Harapan PHC (38 cases, 29.46%) and Yowari General Hospital

Table 1. Papua's Malaria Patient Demographic Overview

Characteristic	Region			Total (n=128)	Percentage (%)
	Jayapura City (n)	Jayapura District (n)	Mimika District (n)		
Age					
<10 years old	0	6	16	22	17.05
11-20 years old	10	19	14	43	33.33
21-30 years old	5	6	12	23	17.83
31-40 years old	4	4	7	15	11.63
41-50 years old	2	4	8	14	10.85
>51 years old	0	4	7	11	8.53
Sex					
Male	14	22	31	67	51.94
Female	7	21	33	61	47.29
Ethnicity					
Papua	6	38	34	78	60.47
Non-Papua	15	5	30	50	38.76
Duration of stay					
<1 year	1	4	11	16	12.40
2-5 years	7	6	16	29	22.48
>5 years	13	33	37	83	64.34
Health Care Facilities					
PHC Koya Barat	15	-	-	15	11.63
PHC Hamadi	6	-	-	6	4.65
PHC Harapan	-	38	-	38	29.46
General Hospital Yowari	-	5	-	5	3.88
PHC Pasar Sentral	-	-	20	20	15.50
PHC Wania	-	-	11	11	8.53
PHC Karang Senang	-	-	20	20	15.50
PHC Timika Jaya	-	-	13	13	10.08
Total Every Region	21	43	64	128	

(5 cases, 3.88%), respectively. In other study areas, it was found that Koya Barat PHC had the highest number of cases in Jayapura City (15 cases, 11.63%), while in Mimika Regency, there were PHC Pasar Sentral and PHC Karang Senang (20 cases each, 15.50%) (Table 1).

Based on the results of the analysis, Mimika district had the highest number of malaria infections, followed by Jayapura district and Jayapura city (Table 1). The results of the analysis show a regional ranking based on the number of malaria cases that is different from the malaria case data from the Ministry of Health of the Republic of Indonesia. The difference lies in the difference in the order of the number of cases between Jayapura District and Jayapura City. Jayapura City is ranked second with the highest number of malaria cases in Papua, while in the study, it is occupied by Jayapura District (Kemkes RI, 2022). This may be due to differences in the time of study data collection, the location of the study used, the source of secondary data, and may be caused by the limitations of the study conducted. In addition, based on the results of the health worker facility mapping study in Papua Province, it is known that Jayapura District and Jayapura City fall into different health worker ratio cluster groups. Jayapura District was categorized as having a low health worker ratio, while Jayapura City was categorized as having a medium health worker ratio (Afrida & Wulandari, 2022). The results of a study conducted by Wijaya *et al*. revealed a correlation between health services and malaria incidence rates (OR=5) (Wijaya *et al*., 2017).

Out of the 128 individuals diagnosed with malaria in the three districts/cities, the majority of patients diagnosed with malaria had resided in their respective areas for more than 5 years, accounting for 83 individuals or 64.34% of the total (Table 1). Among these districts/cities, the highest number of cases was observed in the age group of 11-20 years, with a total of 43 individuals, accounting for 33.33% of the cases (Table 1). Following this age group, the 21-30 years age group had 23 patients, representing 17.83% of the cases. The age group below 10 years had 22 patients, making up 17.05% of the cases. Moreover, the age group of 31-40 years had 15 patients (11.63%), the age group of 41-50 years had 14 patients (10.85%), and the age group above 51 years had the lowest number of cases, with 11 patients (8.53%). Furthermore, the study revealed that there were more male patients than female patients in all three regions (Table 1). Specifically, there were 67 males, accounting for 51.94% of the cases, and 61 females, representing 47.29% of the cases. However, the ratio between males and females remained relatively balanced, with a ratio of approximately 1:1. This balanced ratio was observed in two regions, namely Jayapura District and Mimika District. In Jayapura City, however, the ratio of male to female patients was 2:1, with 14 male patients and 7 female patients.

The topographical characteristics of the region can cause the incidence of malaria cases in a region. Mimika, which is one of the areas with the highest malaria cases in Papua and Indonesia, can be caused by unsanitary environmental factors, the presence of many puddles, bushes, and animal cages around where people live in Mimika Regency (Nurhadi *et al*., 2011). In addition, based on its topography, the Mimika Regency area is quite diverse because it has highland, lowland, and coastal areas. The topography of the Jayapura Regency consists of 146,575 hectares of swamps, 21 rivers, and coastal areas. Jayapura City has a regional topography consisting of highlands, hills, mountains, and coastal areas. These various topographies can serve as breeding and resting places for malaria vectors, such as puddles, swamps, brackish water, river mouths, and hilly areas (Nabatanzi *et al*., 2022). The Jayapura Regency area, which has relatively many swamps and waters, and the Jayapura City area, which has a relatively high elevation, may explain why there are more malaria cases in Jayapura Regency than in Jayapura City. The higher the elevation, the lower the temperature, which may result in changes in the composition of malaria vector species. For example, a study in Uganda showed lower vector density in highlands compared to lowlands (Lindblade *et al*., 2000).

Malaria patients in the 3 districts/cities who came from the Papuan tribal group totaled 78 people, while those from the non-Papuan group totaled 50 people. Table 2 illustrates the tribal distribution of malaria patients based on Papuan and non-Papuan groups. In the group of malaria patients found in the Papuan tribal group in 3 districts and or cities, the highest number of Papuans was 26 people (33.33%), while in the group of patients found in the non-Papuan group, the Javanese tribe dominated, totaling 14 people (28%). The distribution of tribal groups of malaria patients by region found that the tribal group in Jayapura City with the highest number was the Biak tribe, totaling 2 people, while in Jayapura Regency, it was the Papuan and Sentani tribes, totaling 14 people, and in Mimika Regency, it was the Papuan tribe, totaling 12 people.

In 128 malaria patients in 3 districts/cities in Papua, 57 cases of malaria infection caused by *P. falciparum* (44.53%), 41 cases of P. *vivax* (32.03%), 12 cases of *P. malariae* (9. 38%), Mix (*P. falciparum* + *vivax*) numbered 11 people (8.59%), *P. ovale* numbered 4 people (3.13%), Mix (*P. falciparum* + *malariae*) numbered 2 people (1.56%), and Mix (*P. vivax* + *malariae*) numbered 1 person (0.78%) (Table 3). Most malaria cases in 3 districts/cities in Papua are caused by *Plasmodium falciparum* and *Plasmodium vivax* infections. In Jayapura City, the incidence of malaria found was more caused by *P. vivax* than *P. falciparum,* with a ratio of 2:1. In Jayapura District, the

Table 2. Overview of the Malaria Patient Tribal Group Proportion in Papua

	Ethnicity Jayapura City (n)	Region			Total (n=128)	Percentage (%)
		Jayapura District (n)	Mimika District (n)			
Papua						
	Papua	0	14	12	26	33.33
	Yahokimo	1	0	0	1	1.28
	Biak	2	3	1	6	7.69
	Sentani	1	14	0	15	19.23
	Bintang Mountains	0	2	0	2	2.56
	Balak	0	1	0	1	1.28
	Merauke	0	1	0	1	1.28
	Kaimana	1	0	0	1	1.28
	Kayupulah	1	0	0	1	1.28
	Dani	0	2	11	13	16.67
	Waropen	0	1	0	1	1.28
	Damai	0	0	1	1	1.28
	Kei	0	0	5	5	6.41
	Moni	0	0	4	4	5.13
	Total	6	38	34	78	
Non Papua	Ambon	3	1	4	8	16
	Maluku	1	0	2	3	6
	Flores	2	0	4	6	12
	Sumba	0	0	1	1	2
	Jawa	3	3	8	14	28
	Sunda	0	0	1	1	2
	Sulawesi-Bone	1	0	0	1	2
	Sulawesi-Makassar	1	1	1	3	6
	Sulawesi-Kendari	1	0	0	1	2
	Sulawesi-Bugis	2	0	2	4	8
	Sulawesi-Manado	0	0	2	2	4
	Batak	1	0	0	1	2
	Manggarai	0	0	2	2	4
	Toraja	0	0	3	3	6
	Total	15	5	30	50	

highest incidence of malaria was caused by *P. falciparum*, totaling 24 people, followed by *P. vivax*, totaling 11 people. In Mimika District, the highest incidence of malaria was caused by *P. falciparum* with 26 cases and *P. vivax* with 16 cases.

Out of 128 data spread across 8 health facilities in 3 districts of Papua, it was found that the highest number of malaria patients were at Puskesmas Harapan with 38 patients, while the fewest malaria patients were found at General Hospital Yowari (Table 4). Malaria infection caused by *Plasmodium falciparum* was dominant in 5 health facilities, namely Harapan Health Centre (21 patients), Yowari Hospital (3 patients), Pasar Sentral Health Centre (9 patients), Wania Health Centre (3 patients), and Timika Jaya Health Centre (8 patients). However, there were 2 health facilities with more dominant cases of *Plasmodium vivax*

Table 3. Proportion of Malaria Cases in 3 Districts and or Cities in Papua Based on *Plasmodium* Species

Type of Infection	RT-PCR Results				
	Jayapura City	Jayapura District	Mimika District	Total (n=128)	Percentage (%)
P. falciparum	7	24	26	57	44.53
P. vivax	14	11	16	41	32.03
P. ovale	0	0	4	4	3.13
P. malariae	0	3	9	12	9.38
Mix (P. falciparum + P. vivax)	0	4	7	11	8.59
Mix (P. falciparum + P. malariae)	0	1	1	2	1.56
Mix (P. vivax+ P. malariae)	0	0	1	1	0.78
Total	21 (16.4%)	43 (33.6%)	64 (50%)	128	

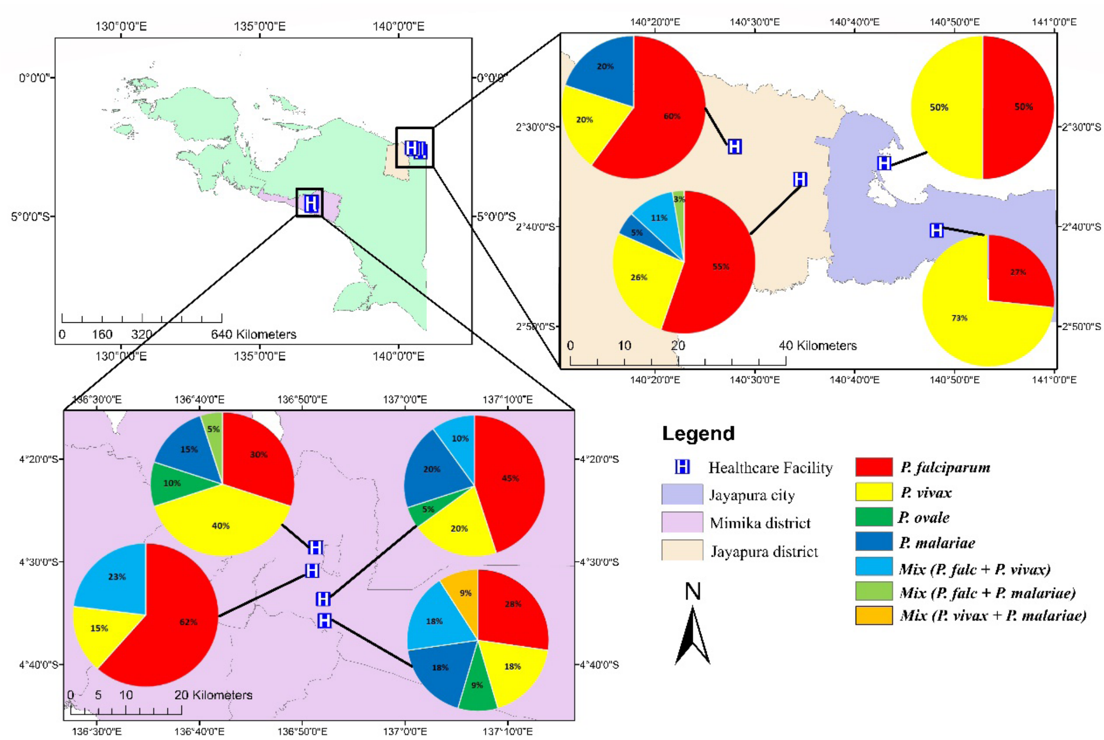

Figure 1. Proportional Distribution Map of Malaria Cases in Three Districts-Cities Papua 2023

Table 4. Distribution of malaria cases in Papua's healthcare facilities based on *Plasmodium* species

Health Care Facilities	RT-PCR Results						
	P.	P. vivax	P. Ovale	P.	Mix (P. Falc + P. Vivax)	Mix (P. falc+ P. malariae)	Mix (P. Viv + P. Malariae)	Total
PHC Koya Barat	4	11	0	0	0	0	0	15
PHC Harapan	21	10	0	2	4	1	0	38
PHC Hamadi	3	3	0	0	0	0	0	6
General Hospital Yowari	3	1	0	1	0	0	0	5

PHC Pasar Sentral	9	4	1	4	2	0	0	20
PHC Wania	3	2	1	2	2	0	1	11
PHC Karang Senang	6	8	2	3	0	1	0	20
PHC Timika Jaya	8	2	0	0	3	0	0	13
Total	57	41	4	12	11	2	1	128

infection, namely Koya Barat Health Centre and Karang Senang Health Centre. There were also equal numbers of *P. falciparum* and *P. vivax* cases at Hamadi Health Centre. Puskesmas Hamadi is also the health facility that found the most *Plasmodium vivax* cases compared to other health facilities. The highest number of *Plasmodium ovale* infection cases was found at Karang Senang health centre. Puskesmas Pasar Sentral is the health facility that found the most cases of *Plasmodium malariae* infection compared to other health facilities. Most cases of combined infection between *P. falciparum* and *P. vivax* were found at Puskesmas Harapan (4 cases), while the combined infection of *P. vivax* and *P. malariae* was only found at Puskesmas Wania (1 case).

At health facilities in Mimika district, cases of malaria infection caused by *Plasmodium falciparum* were the most prevalent (Figure 1). However, at Karang Senang PHC, cases of infection caused by *Plasmodium vivax* accounted for the largest proportion (40% of total cases), and cases of infection due to *Plasmodium falciparum* ranked second (30% of cases). Infections caused by *Plasmodium falciparum* and *Plasmodium vivax* can be found in all health facilities in Mimika District (Figure 1). The least proportion of monoinfection cases was caused by *Plasmodium ovale* at PHC Pasar Sentral (5% of total cases). *Plasmodium ovale* infection was not found at PHC Timika Jaya. Cases of *Plasmodium malariae* infection were not found at PHC Timika Jaya (Figure 1). Of the 4 health facilities, only 3 found cases of combined *Plasmodium falciparum* and *Plasmodium vivax* infection, namely PHC Pasar Sentral, PHC Wania, and PHC Timika Jaya (Figure 1). The highest number of Mix (*P. falc* + *P. vivax*) cases was found at PHC Timika Jaya and had the largest proportion of malaria cases in a health facility (23% of cases). Mix (*P. falc* +P. *malariae*) cases were only found in one health facility, PHC Karang Senang, with a proportion of 5% of the total cases (Figure 1). Mixed cases (P. *vivax* + P. *malariae*) were only found at PHC Wania, with a proportion of 9% of cases.

Plasmodium falciparum infection cases were also the dominant cases found in Jayapura District (Figure 1). The highest proportion of *Plasmodium falciparum* infection cases was found at Yowari Public Hospital (60% of total cases). At PHC Harapan, *Plasmodium vivax* infection cases were the second most common (24%), while at Public Hospital Yowari, cases due to *Plasmodium vivax* and *Plasmodium malariae* infections had equal proportions (20% of cases). No cases of co-infection were found at Yowari Public Hospital. Cases of co-infection were found at Harapan PHC, with the highest proportion of cases due to *Plasmodium falciparum* and *Plasmodium vivax* co-infection (11% of total cases) and the least due to *Plasmodium falciparum* and *Plasmodium malariae* co-infection (3% of total cases). The fewest cases of monoinfection found at PHC Harapan were due to *Plasmodium malariae* infection (5% of total cases). There were no cases of co-infections or monoinfections other than *Plasmodium vivax* and *Plasmodium falciparum* in Jayapura City (Figure 1). Most monoinfection cases in Jayapura City were caused by *Plasmodium vivax* infection, with the largest proportion of cases found at Koya Barat PHC (73% of total cases). At Hamadi PHC, the number of cases of *Plasmodium vivax* and *Plasmodium falciparum* infection had the same proportion (Figure 1).

In March, Jayapura Regency recorded the highest number of cases compared to other regions, with 43 cases of malaria. There are limitations to the data obtained, namely the absence of case data obtained from the Jayapura City and Jayapura Regency administrative areas in May. Mimika District was the study area that experienced an increase in the number of cases from March to May, from 7 cases to

57 recorded cases. The incidence of malaria cases in the three districts studied was higher in March than in May (Table 4). This may be due to changes in wind direction in the Papua region between March and May. In May, winds with lower moisture content blow from the southeast, while in March, winds with high moisture content blow from the northwest, bringing rain. Rainfall can affect the number of malaria cases and even have a positive impact on mortality from malaria in Indonesia (Faradiba, 2021). Data available for the Jayapura district and city is limited to March only, which is a limitation of this study. However, if we look at March, which is a rainy season month, and the topography of the region, the difference in incidence rates in the two regions can be explained. This is supported by a study from Tanzania, where malaria transmission in the lowlands peaked during the rainy season, while in the highlands it was limited to the summer (Bødker *et al*., 2003). The rainy season can affect malaria infection, causing an increase in the number of cases, as documented in Karnataka state, Mangaluru. Vector density becomes high because of favorable climatic conditions (Punnath *et al*., 2021).

The infecting *Plasmodium* species that had the highest percentage of infections in the 3 districts in Papua in 2023 was *Plasmodium falciparum*. In addition, *Plasmodium vivax* was also the infecting agent with the second highest number of cases after *P. falciparum*. *Plasmodium falciparum* and *Plasmodium vivax,* as one of the most infectious agents of malaria is also documented in the current situation report of malaria in 2022 (Kemkes RI, 2022). *Plasmodium falciparum* may employ multiple receptors on red blood cells to enter and infect various ages of red blood cells, which can explain the large number of cases in the locations observed (Kerlin & Gatton, 2013). However, *Plasmodium vivax* infection tends to be high in some study areas, which can be influenced by the genetic factors of the population living there. The Duffy blood group system antigen plays a significant role in *Plasmodium vivax*'s invasion of red blood cells. The antigen can be encoded by the Fya, Fyb, F3, F4, F5, and F6 gene loci (de Carvalho & de Carvalho, 2011). The Duffy factor is significant because Duffy-positive people produce Duffy Antigen/Receptor for Chemokine (DARC), which is related to both inflammatory reactions and a zone identified by *Plasmodium vivax* Duffy Binding Protein (PvDBP) (Batchelor *et al*., 2011; Moskovitz *et al*., 2023). Furthermore, the expression of the DARC gene is also regulated by the GATA promoter. Individuals who express the Duffy antigen incompletely or not at all are resistant to *Plasmodium vivax* infection of blood cells (Bradley *et al*., 2024). Thus, the distribution of the Duffy gene can influence a population's vulnerability to *Plasmodium vivax* infection. Local populations will be resistant to *Plasmodium vivax* owing to natural selection pressure that causes the expression of the Duffy antigen gene to be omitted in the population; this has been reported in parts of Africa where Red Blood Cells is resistant to *Plasmodium vivax* invasion (Hamblin *et al*., 2002; Hodgson *et al*., 2014). Based on the type of single parasite infection, the number of malaria cases caused by *Plasmodium ovale* is relatively the lowest. The incidence of malaria caused by *Plasmodium ovale* is relatively small in almost all regions of the world (Collins & Jeffery, 2007; Mitchell *et al*., 2020; Weiss *et al*., 2019; Zhang *et al*., 2021). This could be due to the preference of *Plasmodium ovale* to only infect young red blood cells (reticulocytes), so that the probability for *Plasmodium* to be sucked by the vector is lower than others (Okafor & Finnigan, 2023).

Co-infection cases were documented in Mimika Districts, with the highest number of cases caused by *Plasmodium falciparum* co-infection with *Plasmodium vivax*, while co-infection cases between *Plasmodium vivax* and *Plasmodium malariae* were relatively low. The number of cases of co-infection between *Plasmodium vivax* and *falciparum* has also been documented in other studies (Leonard *et al*., 2021; Sun *et al*., 2005). Various factors can influence the incidence of co-infection between *Plasmodium*, such as the characteristics and distribution of malaria species, Anopheles mosquitoes, individual factors, and interactions between them (Mayxay *et al*., 2004). Mimika districts with the highest number of mixed infection cases can be correlated with a high number of malaria cases, and the chance of different *Plasmodium* inoculation at a time or at different times in the host can be high (Mohapatra *et al*., 2012).

Co-infection can occur due to interactions between the vector and the causative agent. In the Papua region, co-infection may be associated with dispersed *Anopheles* species. There are several *Anopheles* species that can be found throughout Papua that can cause mixed infections concurrently, such as *An. farauti* that can cause co-infection with Plasmodium falciparum and vivax or malariae or *An. punctulatus* that can cause co-infection with *Plasmodium falciparum* and *vivax* (Mckenzie & Bossert, 1997). Given the vector's ability to facilitate 2 different Plasmodium species at a time, this may explain why the incidence of mixed infections between *Plasmodium falciparum* and *vivax* is highest compared to other mixed infection cases in the Papua province. The absence of *Anopheles* mosquitoes that can carry *Plasmodium ovale*, along with other plasmodiums may explain the absence of mixed infections of *Plasmodium ovale* with other plasmodiums (Mckenzie & Bossert, 1997).

Mimika district has several species of *Anopheles* mosquitoes that can cause mixed infections concurrently, such as *An. farauti* and *An. punctulatus*. In addition, there are several *Anopheles* mosquito species that can carry different Plasmodium species individually. Species such as *An. bancrofti*, *An. koliensis*, *An. longirostris* that can be found in Mimika Regency can carry *Plasmodium falciparum* or *vivax* singly, while *An. tesselatus* can carry *Plasmodium malariae*, *falciparum*, or *vivax* singly (Mckenzie & Bossert, 1997; Rizki *et al*., 2019). Jayapura district has a similar composition of Anopheles mosquitoes to Mimika district, but *An. bancrofti* was not found in this district (St. Laurent *et al*., 2016). Although some of the same Anopheles mosquito species can be found in Jayapura city, no Plasmodium falciparum or vivax were found simultaneously in mosquitoes (Sorontou & Hastuty, 2019).

Mixed *Plasmodium* malaria infections were documented to cause a severe case of malaria with potential complications of anemia, pulmonary, and urinary system (Kotepui *et al*., 2020). The incidence of co-infection between *Plasmodium* can affect the success of malaria control programs, elimination efforts, and effective clinical treatment (Leonard *et al*., 2021). This sparks some concerns because the cases are often left out and underestimated in common study and it can increase the potential resistance on malarian medicines (Tajebe *et al*., 2014), so we have documented potential information regarding these cases occurring in Papua.

The proportion of infecting *Plasmodium* in this study resembled previous studies, although in Jayapura City, malaria cases due to *Plasmodium vivax* infection were more dominant than *Plasmodium vivax* (with a ratio of 2:1) (Table 3). Reflecting on the demographic conditions of malaria patients recorded in Jayapura City, most (15 out of 21 patients) were of non-Papuan ethnicity (Table 1). The situation where cases of infection due to *Plasmodium vivax* are more prevalent in non-indigenous groups in an area has also been found in other studies (de Aguiar *et al*., 2022). This can be a particular concern because there is a possibility of imported cases due to population movements, possibly to their place of origin. Import cases can occur because, as a result of *Plasmodium vivax* infection, *P. vivax* can cause a latent infection due to its hypnozoite forms (Flannery *et al*., 2022). With the hypnozoites that can be formed by *P. vivax* infection, relapse or recrudescence can occur, so that it can cause imported cases in non-endemic areas, as is the case happen in China (Cui *et al*., 2021; Yan *et al*., 2023). Imported cases are also caused by the activities of travelers in the human population. Migration is one of the important risk factors causing imported cases to occur in non-endemic areas. This case is also recorded in a study in West Java province, which can potentially lead to re-verification of the eliminated status because of imported cases and locally transmitted cases being found in the area. It is also found among duty soldiers and police who return from Papua (Fauziah *et al*., 2024).

There are some notable differences in the proportion and number of malaria infection cases in each health care facilities within the study areas (Table 4). There are two contrasting findings in Jayapura District, in which there is a considerable difference in the number of cases between Harapan Health Center and General Hospital Yowari. However, the proportion of infecting agents between the two is quite similar. The difference in the number of cases may be influenced by the difference in location between the two health facilities, where Harapan Health Center is located in Sentani Timur sub-district, while General Hospital Yowari is located in Waibu district/district. This is reinforced by the presence of freshwater bodies in the form of lakes in the East Sentani sub-district, which can be a breeding ground for malaria vectors, while the Waibu district area is more located in the highlands. In addition, based on a study by Hastuty *et al*., in the East Sentani district revealed that the environmental conditions around where people live are less clean, and there are many areas of bushes, swamps, ditches, and puddles on tire tracks that can become nests for Anopheles mosquitoes to breed (Hastuty & Setyowati, 2021). In contrast to the proportion of infecting *Plasmodium* in the district area, Jayapura City has a higher proportion of infection cases due to *Plasmodium vivax* than *P. falciparum*. This may be attributed to the number of people of non-Papuan ethnicity living in Jayapura City compared to Jayapura Regency. However, this study did not analyze the relationship between the presence of non-Papuans and the incidence of malaria in the districts of Papua. In Mimika District, 2 health facilities have the same number of cases, but with different proportions of *Plasmodium* infection, namely PHC Pasar Sentral and PHC Karang Senang. Patients with malaria due to *Plasmodium vivax* infection were more numerous than those due to *Plasmodium falciparum* at Karang Senang Health Center. The two health centers are located in different sub-districts. Karang Senang Health Center is in the Kuala Kencana sub-district, while Pasar Sentral Health Center is in the Mimika Baru sub-district. No study has been conducted to study the characteristics of infection in these two areas. There is a possibility that there is a factor of migrants / other tribes who live in the Kuala Kencana sub-district area, because it is related to the presence of Freeport Mining Companies. The disruption of environmental equilibrium and the creation of potential mosquito breeding grounds caused by mining activities, coupled with the influx of workers lacking prior immunity and irregular use of antimalarial drugs, can contribute to a surge in local malaria cases as well as the importation of cases when these workers return to their home regions (Shanks & Wongsrichanalai, 2021). It can also be found that malaria, characterized by high *Plasmodium vivax* infection, can be found in rural and mining settlements (Camargo *et al*., 1994; Duarte *et al*., 2004). In general, populations that can be affected are migrants who come from non-malaria-endemic areas. This is because of the response of the immune system, secreting the Immunoglobulin G of anti-DBP in a host, which can affect *Plasmodium vivax* infection of red blood cells (Cerávolo *et al*., 2005; Tran *et al*., 2005). Malaria programs in a region can also affect the number of cases found. For example, when there was a change in malaria surveillance policy in Papua, the number of malaria cases found increased (45.7% vs 67.3%) (Kenangalem *et al*., 2019).

The incidence of young people (11-20 years old) being the group with the highest number of malaria patients in the study area could be related to the large number of members of this group who are active outdoors at night for various reasons (Moshi *et al*., 2018). Activities outside the home at night can increase the risk of developing malaria in endemic areas (Moshi *et al*., 2018). Several studies also support that age is a factor that plays an important role in influencing a person's risk of developing malaria, such as studies conducted by Hasyim *et al* (APR = 7.685) (Hasyim *et al*., 2023), Khagayi *et al*. (Khagayi *et al*., 2019), Ranjha *et al* (Ranjha *et al*., 2023), and others. Furthermore, based on a study conducted by Lendongo *et al*, there are several things that can affect malaria incidence in the 0-18 year age group, including parental/guardian knowledge and malaria prevention by parents/guardians (Lendongo *et al*., 2023). However, this study did not analyze the relationship between age and malaria incidence rates in the 3 districts of Papua.

Malaria patients are mostly male, as found in the national malaria report in 2022. It is also known that men have a higher risk of developing malaria than women in a study (OR = 4.57) (Abdalal *et al*., 2023; Kemkes RI, 2022). A retrospective study in a paediatric polyclinic conducted at Dekai General Hospital, Yahukimo Regency, found that malaria infections were more common in males (53.7%) with a male-to-female ratio of 1.2:1 (Dewi *et al*., 2019). However, a study from Uganda states the opposite, that malaria incidence is higher in females (IRR = 1.72) (Okiring *et al*., 2022). While this study did not analyze the relationship between factors that may cause the high incidence of malaria in the area, with the analysis being done, we can picture the same risk between the area of the study and other areas. Men are at higher risk due to more frequent night activities due to their role as breadwinners and occupations such as farmers, forest workers, etc (Ramdzan *et al*., 2020). It is also known that according to the National Statistic Centre (BPS), Papua has one of the highest men to women ratio in terms of population in 2022. Based on the data obtained from a study in the province of Papua, most of the heads of families have jobs as farmers (61%). This makes it possible for these workers to get malaria because they work close to the breeding grounds of mosquitoes. Another study, which did not mention the gender of the subjects, confirmed that in the Jayapura district, many individuals have the habit of being outside at night but rarely use personal protection, and the subjects rarely clean the environment, which can allow the development of mosquito breeding grounds (Madayanti *et al*., 2022).

Future research using primary data and direct analysis could address this gap. Additionally, the study's reliance on available data may have led to insufficiencies in conducting intended analyses and raised concerns about potential bias in results due to a minimal number of data samples. Future research using primary data and direct analysis could address this gap. Geographical analysis was also constrained by limited location coordinate data of patients within the secondary dataset and the restricted coverage of the study area. However, despite these limitations, the study provides a basic understanding of malaria case distribution in three high-endemicity areas in Papua, which can support malaria elimination programs, but further investigations are essential for identifying factors that can influence these rates and facilitating effective formulation of prevention programs

Conclusion

A study of the distribution of malaria cases in Papua is one of the essential things to know because Papua is the region with the highest number of malaria cases in Indonesia. The highest distribution of malaria cases in 3 districts in Papua in 2023 based on age is the age group 11-20 years, based on gender in males, based on ethnicity is Papuan, based on the duration of stay that has been more than 5 years, based on health facilities at Primary Health Care (PHC) Harapan, and with the highest in Mimika Regency. The most common type of infection is caused by *Plasmodium falciparum*. The distribution map of malaria cases in the 3 districts/cities shows the location of the health facility where the patient came from. The highest number of cases was found at Puskesmas Harapan, which is located in Sentani Timur sub-district.

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