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HIV/malaria co-infection and its determinants among people living with HIV/AIDS in Yenagoa, Bayelsa state, Nigeria

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Abstract

Major public health issues in Nigeria include HIV and malaria. HIV and malaria are two severe global public health issues. We conducted a cross-sectional study. One hundred and four HIV-infected individuals attending an antiretroviral treatment (ART) clinic in Yenagoa, Bayelsa State, were enrolled in this study using a random sampling technique. In order to gather data on the respondents' characteristics, questionnaires were given out. Venous blood samples were collected and analyzed for malaria parasite, CD4, and plasma viral load (PVL) using SD Boline RDT, Partec flow cytometer, and Abbott Real-Time protocol, respectively. All laboratory tests were performed following the manufacturer's instructions. The HIV/Malaria co-infection was 5.0%. A significant risk factor for the co-infection was high CD4 counts ($p = 0.02$). Age ($p = 0.76$), sex ($p = 0.54$), marital status ($p = 0.47$), education ($p = 0.75$), occupation ($p = 0.57$) and PVL ($p = 0.39$) were not significant ($p > 0.05$) risk factors. Though, a higher HIV/malaria co-infection occurred in the age group 21-40 years (6.0%), males (7.0%), CD4 counts >500 cells/µl (15.4%) and PVL <20 copies/ml (7.5%). In Yenagoa, Nigeria, the occurrence of HIV/malaria among PLWHA has been further established by the current study. Whereas their female counterparts showed a more significant propensity to HIV infection alone, males were more susceptible to HIV/Malaria co-infection. High CD4 levels were a significant risk factor for co-infection with HIV and malaria. HIV status did appear to affect a person's propensity to contract malaria, as HIV-positive individuals in Yenagoa, Nigeria, were shown to be more susceptible to the disease. We, therefore, urge that individuals living with HIV/AIDS be prioritized for any malaria intervention because of their vulnerability to malaria.

Keywords: ART; Co-infection; HIV; Malaria; PLWHA; Prevalence

1. Introduction

Plasmodium parasites, which individuals' contract through the bites of infected female Anopheles mosquitoes, are the source of the acute fever sickness known as malaria. It is treatable and preventive (WHO, 2023). Malaria is still a problem for global public health (Omatola & Okolo, 2021). According to the World Health Organization's (WHO) most recent estimates, this disease still affects about 3.2 billion people (41.0 per cent of the world's population) (Scotto & Fazio, 2018). A 2020 World Health Organization analysis found that malaria caused 229 million infections and 409 000 deaths worldwide (WHO, 2020). According to the most current World Malaria Report, there were 247 million malaria cases in 2021, up from 245 million in 2020 (WHO, 2022).

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Nigeria, with a total of 27.0% of cases worldwide, is in front of the six countries that account for more than half of all malaria cases, followed by the Democratic Republic of the Congo (12.0%), Uganda (5.0%), Mozambique (4.0%), Côte d'Ivoire, Angola, and Niger (3.0% each) (WHO, 2020; Omatola & Okolo, 2021; Okonko et al., 2023). According to reports, malaria is also to blame for 5–14% of low birth weight, 15% of maternal anaemia, and 70% of the morbidity among pregnant women in Nigeria (Onyemaechi & Malann, 2020; Haider, 2021).

Human immunodeficiency virus (HIV) can compromise the immune system, making the person susceptible to several illnesses (Zhang et al., 2011; Ohunene et al., 2023). Globally, roughly 37.9 million people are living with HIV, of whom about 24.5 million are receiving treatment (Ohunene et al., 2023). This heavily impacts resources in underdeveloped countries (UNAIDS, 2019). According to estimates from UNAIDS and the National Agency for the Control of AIDS, 1.9 million HIV-positive people live in Nigeria (Ohunene et al., 2023), with about 30,000 of them residing in Bayelsa State, where the HIV prevalence is 1.9% (USAID, 2021).

Major public health issues in Nigeria include HIV and malaria (Avert, 2015; NMEP/ NPopC/NBS/ICF, 2016; Gumel et al., 2021). HIV infection impairs human immunity, making people more vulnerable to other illnesses like malaria (Douek et al., 2009; Aboud et al., 2010; WHO, 2021). On the other hand, *Plasmodium*, a single-celled microbe that infects red blood cells, is the cause of malaria, which has a higher propensity for severity and death in the presence of immunosuppression (Aboud et al., 2010). Also, it has been shown that HIV morbidity and death increase when malaria and HIV co-infection coexist (Uju et al., 2013; Gumel et al., 2021).

HIV and malaria are two severe global public health issues (Gumel et al., 2021; Guerra et al., 2022). There is a significant geographic overlap between them globally, with the majority of those affected residing in sub-Saharan Africa, the Indian subcontinent, Southeast Asia, Latin America, and the Caribbean (Frischknecht & Fackler, 2016; Guerra et al., 2022). They result in more than two million yearly fatalities (Gumel et al., 2021). According to numerous studies (Korenromp et al., 2005; Skinner-Adams et al., 2008; Secretaria de Vigilância em Sade, 2019; Guerra et al., 2022), millions of people die each year as a result of HIV/Malaria co-infections, which are made more likely by this overlap.

Recent hypotheses have proposed that there may be a high likelihood of HIV-malaria co-infection wherever the two diseases' geographic overlap occurs (Gumel et al., 2021). More than 29 million people in sub-Saharan Africa alone are HIV/AIDS positive, and roughly 70% of the population is at risk for malaria infection (Gumel et al., 2021). About one-tenth of all HIV and one-quarter of all malaria cases worldwide are reported from Nigeria.

According to reports, HIV and malaria co-infection can occur whenever there is a high incidence of the two infections (Idemyor, 2007; Kwenti, 2018; Gumel et al., 2021), and individuals who have both diseases co-infected are more likely to experience harmful interactions between them (Idemyor, 2007; Aboud et al., 2010; Uju et al., 2013). The co-infection is likely to make some consequences, including anaemia, which is common to both HIV and malaria, worse (Tay et al., 2015). HIV and malaria interactions in coinfected people have a negative impact on the course of both diseases, notably in pregnant women and children born to mothers who have HIV (Kamya et al., 2006; WHO, 2015; Gumel et al., 2021).

Malaria infection rates have reduced in most of Nigeria's states, but the southern and north-central geopolitical zones have seen the most significant reductions (Haider, 2021; Oyibo et al., 2021). HIV and malaria prevalence statistics differ by state (Haider, 2021). Rural areas have a higher risk of contracting malaria and developing malaria-HIV co-infection, partly because there is less access to healthcare services and household affluence than in metropolitan areas (Bassey & Izah, 2017; Ugwu & Zewotir, 2020; Gumel et al., 2021; Haider, 2021). Many researchers have looked at how HIV and malaria interact in Nigeria. Each disease may become more severe and possibly more contagious through co-infection (Chukwuocha et al., 2019; Gumel et al., 2021; Jemikalajah et al., 2021).

The impairment of parasite control brought on by HIV-1-associated immunosuppression is most likely connected to increased Plasmodium parasitaemia (Whitworth et al., 2000; Patnaik et al., 2005; Chavale et al., 2012; Ejike et al., 2020a). Malaria complications are more likely to occur in patients with low CD4+ T cell counts of fewer than 350 cells/mm3 (Cohen et al., 2005; Mouala et al., 2009; Chavale et al., 2012; Ejike et al., 2020a). Also, *P. falciparum* malaria with HIV-1 infection has a higher prevalence of anaemia (Otieno et al., 2006; Davenport et al., 2010; Chavale et al., 2012; Ejike et al., 2020a).

HIV-1 infection may be affected by malaria (Chavale et al., 2012). Patients with malaria who also have HIV/AIDS may temporarily have fewer CD4+ T cells; this phenomenon may partially improve with effective antimalarial treatment (Van Geertruyden et al., 2006; Chavale et al., 2012; Ejike et al., 2020a). It has yet to be determined if malarial episodes and a reduction in CD4+ T cell counts in HIV-1 patients are related causally (Mermin et al., 2006; Chavale et al., 2012; Ejike et al., 2020a). Cell death may increase due to HIV-1's predilection for infecting memory CD4+ T cells (Grossman et

al., 2002; Chavale et al., 2012). As a result, HIV-1 probably depletes *P. falciparum* coinfection-specific T-cell clones in coinfected patients throughout each bout of malaria (Whitworth & Hewitt, 2005; Mermin et al., 2006; Chavale et al., 2012; Ejike et al., 2020a).

The method by which the coexistence of these two infections can affect the immunopathogenesis of HIV/*P. falciparum* co-infection is still debated (Chavale et al., 2012; Ejike et al., 2020a). HIV plasma viral load (PVL) is thought to be predicted by viral replication, a well-known mechanism that contributes to lymphocyte activation (Benito et al., 2004; Ejike et al., 2020a). The risk of HIV transmission can increase because acute malaria increases the HIV PVL (Kublin et al., 2005; Chavale et al., 2012). Moreover, according to Worku et al. (2007), Plasmodium antigens cause high cellular activation, which may promote HIV-1 infection and replication from scratch (Froebel et al., 2004; Chavale et al., 2012). As a result, these elements (CD4 counts and plasma viral loads) can weaken the immune system's response to both HIV and P. falciparum and speed up the development of HIV illness (Chavale et al., 2012; Ejike et al., 2020a).

Although research on co-infection with the most common form of malaria has been neglected in some regions of Nigeria, there has been significant evidence of a relationship between the increased risk of falciparum malaria among HIV-infected individuals during the past three decades (Guerra et al., 2022). To the best of our knowledge, there is a dearth of literature on HIV/Malaria co-infection among HIV-positive individuals and related determinants in Bayelsa State, Nigeria. Identifying its determinants will aid prevention and quick response (Nwaneli et al., 2020). In order to establish a baseline of knowledge, this study was conducted to ascertain the prevalence of HIV/Malaria co-infection among HIV-positive individuals in Yenagoa, Nigeria.

2. Material and methods

2.1. Study Area

Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria, is one of the main treatment facilities for people living with HIV and AIDS (PLWHA) in Bayelsa State, Southern Nigeria. Yenagoa is a Local Government area and capital city of Bayelsa State, Nigeria. It is located in the southern part of the country. The LGA has an area of 706 km^2 and a population of over 352,285 as of 2006. The Ijaw form the majority of the state. Bayelsa is also situated in swamps, mangroves, and tropical rainforests. It can be found in the centre of the Niger Delta area. One of the newest states in the federation, Bayelsa, was created from Rivers State in 1996. The state bothers River State, which it was formerly part of and Delta state. The state is the smallest in Nigeria by population as of the 2006 Census and one of the smallest by area. Bayelsa State has a riverine and estuarine setting, with bodies of water preventing the development of significant road infrastructure. Petroleum is the primary sector of the Bayelsa economy.

2.2. Study Design

A hospital-based cross-sectional study design was adopted for the study. The method for this study consists of informed consent, blood withdrawal by venipuncture, screening for HIV/Malaria co-infection, enumeration of CD4 counts, and plasma viral loads.

2.3. Ethics statement

Administrative approval was obtained from the management of the Federal Medical Centre, Yenagoa, Nigeria. Ethical considerations and approval were obtained from the University of Port Harcourt Research Ethics Committee following the ethics for research involving human subjects. Before samples were taken and processed, everyone who participated gave informed consent. The World Medical Association's (WMA) Declaration of Helsinki, which sets forth the guidelines for medical research involving identified human/animal subjects, human subjects, and animal subjects, was followed in the conduct of this study.

2.4. Study population

One hundred and four HIV-infected individuals attending the antiretroviral treatment (ART) clinic of Federal Medical Centre in Yenagoa, Bayelsa State, were enrolled in this study using a random sampling technique. Only participants who willingly gave informed consent and volunteered to have their blood samples examined were recruited into the study. At the same time, HIV-infected participants who had incomplete data and duplicate records were excluded from the study. Those on anti-malaria or antibiotics were also excluded from the study.

2.5. Data and Sample collection

Blood samples of HIV-infected individuals were collected by the venipuncture method. About 3 ml of venipuncture blood was collected in EDTA BA Vacutainer TM anti-coagulant tubes (BD, Franklin Lakes, USA), labelled with each patient's code. Socio-demographic data of the participants (sex, age, marital status, educational background, occupation, and use of ART) were collected.

2.6. Serological analysis

Blood samples were tested at the Virus & Genomics Research Unit, Department of Microbiology, University of Port Harcourt, for the presence of malaria *Plasmodium falciparum* Antigen using SD Boline RDT kit (Standard Diagnostics Pvt. Ltd., Gurgaon, Haryana, India). Laboratory testing was carried out according to the manufacturer's instructions, and all tests were run using quality controls according to standard operating procedures.

2.7. CD4 and Viral Load Analysis

Each participant's viral load was estimated using Polymerase Chain Reaction (PCR) on Abbott Real-Time equipment. Their CD4 count was determined using a Partec flow cytometer (Partec GmbH, Germany) in accordance with the manufacturer's instructions.

2.8. Data analysis

Prevalence of HIV/Malaria co-infection among PLWHA was compared to CD4+ T cell count, viral loads and socio-demographic variables using Pearson's chi-square (χ^2) test or Fisher's exact test, where appropriate. Data were analyzed using SPSS version 20.0 (SPSS Inc. Chicago, IL, USA). Statistical significance for all analyses was determined at a 5% significance level.

3. Results

3.1. Study Population Characteristics

One hundred and four participants were enrolled in this study. The average age of the participants was 39 years (8 - 72 years). Seventy-five participants (72.1%) were females, 56 (53.9%) were married, 43 (41.4%) had secondary education, 29 (28.0%) were doing business or trading, 54 (52.0%) had CD4 cell counts of <200 cells/µl, 53 (51.0%) had a viral load of <20 copies/ml and 103 (99.0%) were on Tenofovir, Lamivudine, and dolutegravir (TLD) ART drugs while only one person (1.0%) was on Abacavir, Lamivudine and Efavirenz (ABC/3TC/EFV) (Table 1).

Table 1 Patients Characteristics

Variables	Categories	No. Tested	Percentage (%)
Age groups (Years)	8-20	8	7.7
	21-40	51	49.0
	41 & above	45	43.3
Sex	Females	75	72.1
	Males	29	27.9
Marital Status	Singles	43	41.4
	Married	56	53.9
	Divorced	5	4.8
Educational Background	Primary	17	16.4
	Secondary	43	41.4
	Tertiary	42	40.4
	None	2	1.9
Occupations	Self-Employed	27	26.0

	Unemployed	10	9.6
	Business/Trader	29	28.0
	Students	23	22.1
	Artisans	7	6.7
	Civil Servants	8	7.7
CD4 Counts (Cells/µl)	<200	54	52.0
	200-349	10	9.6
	350-499	14	13.5
	500 & above	26	25.0
Viral Loads (Copies/ml)	<20	53	51.0
	20-999	41	39.4
	1000 & above	10	9.6
ART Drugs	TLD	103	99.0
	ABC/BTC/EFC	1	1.0
Total		104	100.0

3.2. HIV/MP Co-infection

The HIV/Malaria co-infection rate was 5.0%, and 95.0% had HIV only (Figure 1). The prevalence of HIV/malaria co-infection according to the characteristics of the patients is shown in Figures 2 to 9.

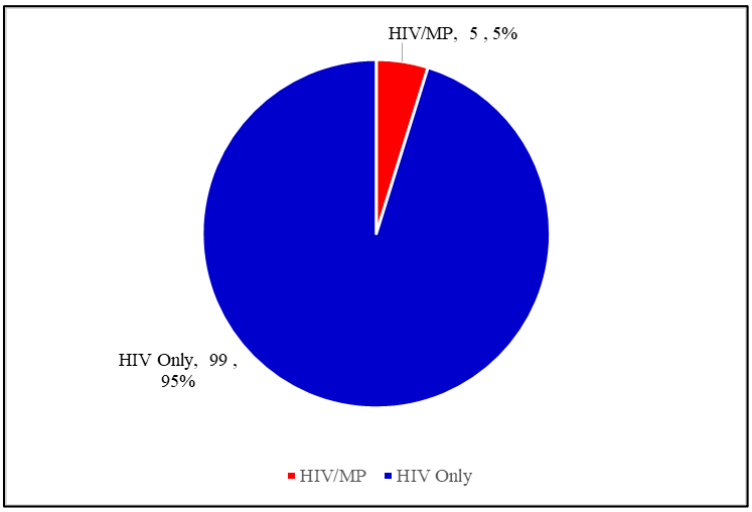

Figure 1 Overall HIV/MP co-infection

3.3. Age-Related HIV/Malaria co-infection

With age, HIV/Malaria co-infection rate decrease with an increase in age, from 6.0% (n = 3) for those within 21 – 40 years to 4.4% (n = 2) for those within 41 years and above. However, this was except for patients that were <20 years who had a 0.0% HIV/Malaria co-infection rate (Figure 2). No significant association existed between the HIV/Malaria co-infection rate and the age groups of the study population (p= 0.76).

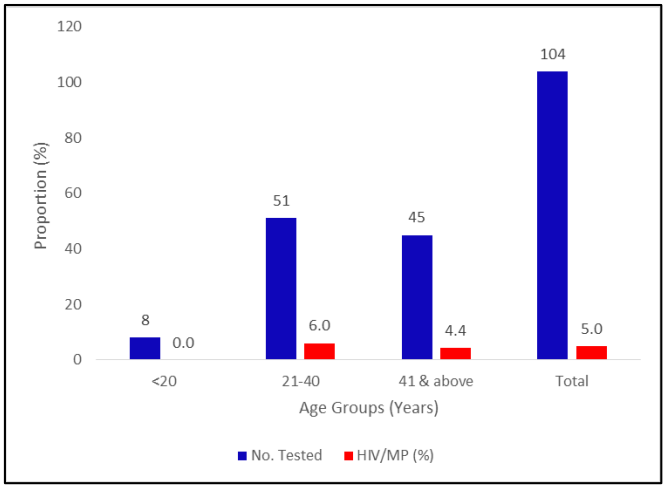

Figure 2 HIV/MP co-infection with age

3.4. Sex-Related HIV/Malaria co-infection

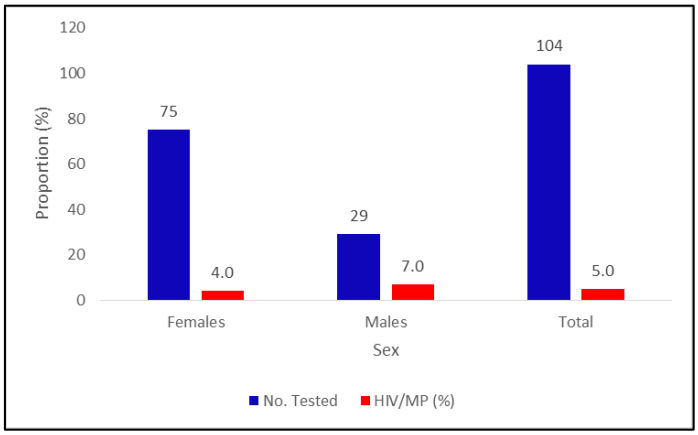

Figure 3 HIV/MP co-infections with Sex

Male participants had a higher HIV/Malaria co-infection rate of 7.0% (n=2) than 4.0% of female participants (Figure 3). No significant association existed between HIV/Malaria co-infection and the sex of the study participants (p= 0.54).

3.5. Marital Status-Related HIV/Malaria co-infection

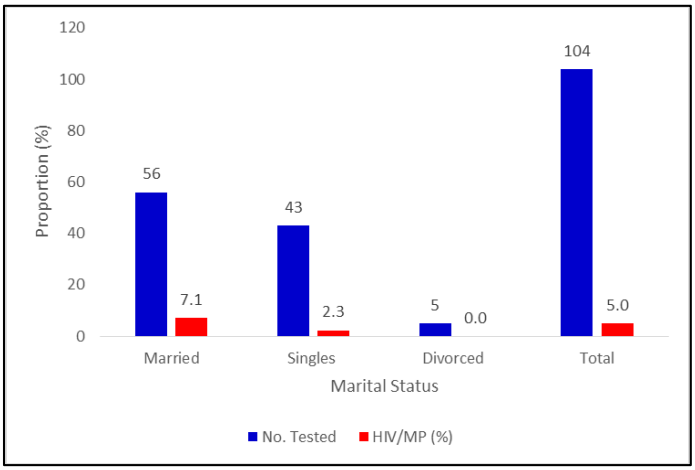

Figure 4 HIV/MP co-infections with Marital Status

Maritally, the highest HIV/Malaria co-infection (7.0%) was recorded for married participants, while singles and divorced had lower rates of 2.3% and 0.0%, respectively (Figure 4). No significant association existed between HIV/Malaria co-infection and marital status (p= 0.47).

3.6. Educational Background-Related HIV/Malaria co-infection

In terms of educational background, the highest HIV/Malaria co-infection rate (7.1%) was recorded for participants that had tertiary education (Figure 5). This result was followed by those with primary education (5.9%), while those with secondary education had a lower rate (2.3%). No significant association was found between HIV/Malaria co-infection and educational background (p= 0.75).

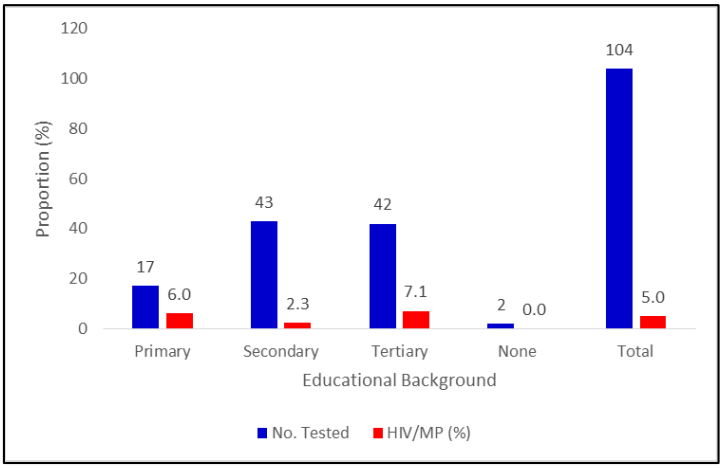

Figure 5 HIV/MP co-infections with Educational Background

3.7. Occupation-Related HIV/Malaria co-infection

Regarding occupation, the highest HIV/Malaria co-infection rate (25.0%) was recorded for civil servants participants. This result was followed by the unemployed (10.0%), those that were self-employed (7.4%) and students (4.3%), while other categories of occupation had a zero HIV/Malaria co-infection rate (Figure 6). No significant association was found between HIV/Malaria co-infection rate and occupations (p= 0.57).

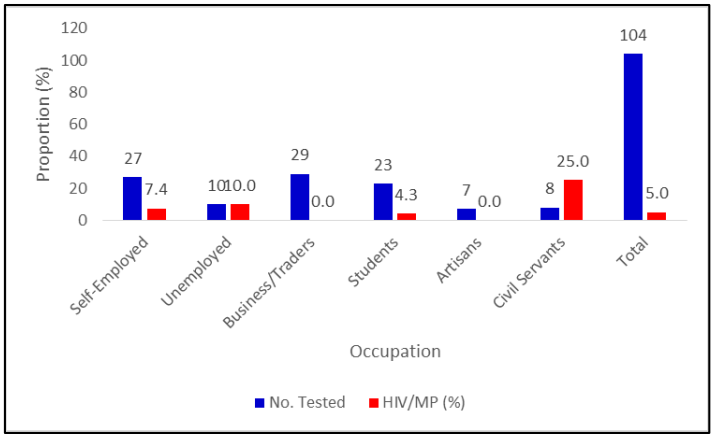

Figure 6 HIV/MP co-infections with Occupations

3.8. CD4 Counts-Related HIV/Malaria co-infection

In terms of CD4 counts, the highest HIV/Malaria co-infection rate (15.4%) was recorded for participants that had CD4 counts of >500 cells/µl, followed by 350-499 cells/µl (7.1%) while zero HIV/Malaria co-infection rate was recorded for <200 and 200-349 cells/µl (Figure 8). A significant association existed between HIV/Malaria co-infection rate and CD4 counts (p= 0.02).

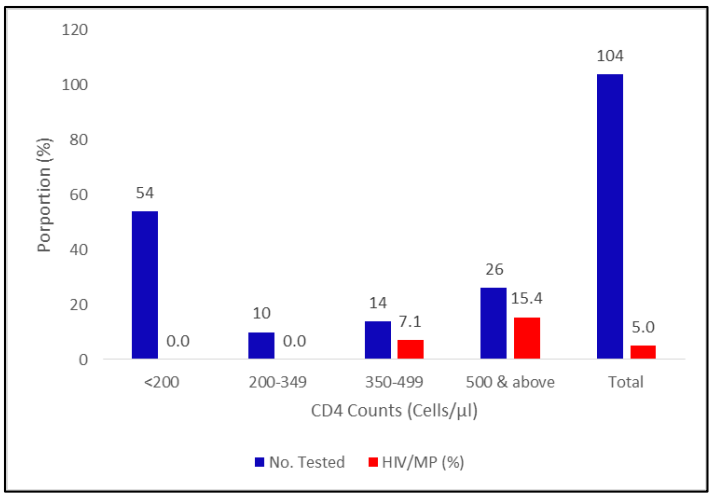

Figure 7 HIV/MP co-infections with CD4 Counts

3.9. Viral Loads-Related HIV/Malaria co-infection

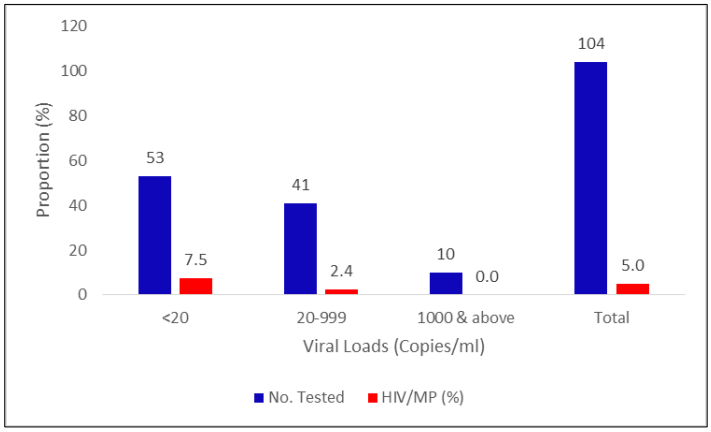

Figure 8 HIV/MP co-infections with Viral Loads

In terms of viral loads, the highest HIV/Malaria co-infection rate (7.5%) was recorded for participants that had <20 copies/ml while those with viral loads 20-999 copies/ml and >1000 copies/ml had lower rates of 2.4% and 0.0%, respectively (Figure 8). No significant association was found between HIV/Malaria co-infection rate and viral loads (p= 0.39).

3.10. ART-Related HIV/Malaria co-infection

All the participants were on Tenofovir, Lamivudine, and dolutegravir (TLD) except for one person on Abacavir, Lamivudine and Efavirenz (ABC/3TC/EFV). A higher HIV/Malaria co-infection rate (4.9%) occurred in participants on TLD than those on ABC/3TC/EFV (0.0%) as shown in Table 2. No significant association existed between the HIV/Malaria co-infection rate and the category of ART drugs ($p > 0.05$).

Table 2 HIV/MP co-infections with ART

ART Drugs	Category	No. Tested (%)	HIV/MP Co-infections (%)
	TLD	103 (99.0)	5 (4.9)
	ABC/3TC/EFV	1 (1.0)	0.0
Total		104 (100.0)	5(5.0)

4. Discussion

Malaria is a significant public health issue, particularly in tropical areas (Tamal et al., 2019). Over 216 million malaria cases and 445,000 fatalities from malaria were reported globally in 2016. (WHO, 2017; Tamal et al., 2019). About 90.0% of worldwide malaria morbidity and 91.0% of malaria-related mortality occur in the sub-Saharan African region (Tamal et al., 2019). Nigeria has the second-highest load of AIDS and human immunodeficiency virus (HIV) in the world and the highest number of malaria cases. The likelihood of HIV patients also having malaria is very high (Gumel et al., 2021). The primary causes of morbidity and mortality in underdeveloped countries are HIV and malaria (Yibeltal et al., 2020). Each disease may become more severe and possibly more contagious through co-infection (Chukwuocha et al., 2019; Gumel et al., 2021; Jemikalajah et al., 2021). HIV therapy reduces the effectiveness of antimalarial medications and may exacerbate side effects (Ssentongo et al., 2020). In order to establish a baseline of knowledge, this study was conducted to ascertain the prevalence of HIV/Malaria co-infection among HIV-positive individuals in Yenagoa, Nigeria. According to the study, the rate of HIV/Malaria co-infection is 5.0%, which is equivalent to the 3.0% found in our prior study in Calabar, South-South Nigeria (John et al., 2020), as well as the 5.0% found in Port Harcourt, South-South Nigeria (Okonko et al., 2021).

When compared to similar studies conducted in Nigeria, the prevalence figures (5.0%) found in this study are incredibly low. This study found that 5.0% of HIV patients also had malaria, which was lower than the 6.3% recorded in Uyo, South-Southern Nigeria (Ejike et al., 2020a), and much lower than the 18.9% from Anambra, Southeast Nigeria (Onyenekwe et al., 2007), 21.0% from Jos, northcentral Nigeria (Uneke et al., 2005), 47.7% from Lagos, Southwestern Nigeria (Sanyaolu et al., 2013), 31.0% from Sokoto, North-western Nigeria (Onankpa et al., 2017), 27.7% from Kano, North-western Nigeria (Jegede et al., 2017) 22.9% in Zaria, Kaduna State, North-western Nigeria (Gumel et al., 2021), 42.4% from Abuja, Federal Capital Territory Nigeria (Enuma et al., 2022), 55.8% from Enugu and Awka, South-eastern Nigeria (Osarumwense et al., 2022) and the 11.5% from Osun State, Southwestern Nigeria (Oyeniran et al., 2022). With malaria, Fana et al. (2015) reported a 41.6% prevalence in Kebbi state, Nigeria. Obimakinde & Simon-Oke (2017) recorded a higher malaria prevalence value of 78.7% in Akure, Nigeria, and Amodu-Sanni et al. (2020) reported 71.4% in Sokoto, Nigeria. These variations may result from the different malaria burdens in the six geopolitical regions of the nation.

The prevalence values (5.0%) recorded here are exceptionally low when assessed against similar studies across Africa. Saracino et al. (2012) recorded 66.7% and 47.2% for HIV and Malaria, respectively; co-infection incidence was 25.9% in Mozambique. Jenkins et al. (2015) reported a 28.0% malaria prevalence in Kenya, while Debo & Kassa (2016) reported a 6.1% incidence in Southern Ethiopia.

It is lower than the 10.3% reported for HIV/Malaria co-infection in Akure, Ondo State, Nigeria (Dada et al., 2016), the 28.0% reported in Jos (Iroezindu et al., 2012), the 15.5% reported from Ghana (Tagoe & Boachie, 2012), the 21.0% reported in Malawi (Kublin et al., 2005), the 93.3% reported in HIV-infected Nigerians (Erhabor et al., 2006); the 31.0% recorded in North-west Nigeria (Onankpa et al., 2017); the 18.5% in Osogbo (Ojurongbe et al., 2014); 14.2% and 14.0% reported among HIV patients in Uyo (Amadi et al., 2018); 14.3% in old Cross River State (Ejike et al., 2020b); 16.2% in North Central Nigeria (Inyama et al., 2016); and lower than 22.9% malaria co-infection prevalence by Gumel *et al.* (2021); 24.0% in Jos (Iroezindu et al., 2012); 56.8% in Keffi (Yohanna et al., 2019); 59.2% in Kaduna (Abioye et al., 2014). Additional studies conducted in different parts of the world revealed that the prevalence of HIV among patients in Cameroon was 14.0% (Sandie et al., 2019); 36.0% (Cohen et al., 2011); 61.7% (Saracino et al., 2012); and, more recently, 17.8% in Osun State (Oyeniran et al., 2022).

This study's prevalence of HIV-Malaria co-infection (5.0%) is higher than other studies conducted in Nigeria. In Lagos, Nigeria, a study found that the frequency of HIV/malaria co-infection was 2.9%. (Sanyaolu et al. 2013). 3.0% resulted from another investigation in Calabar, Nigeria (John et al., 2020). It is also higher than the 4.55% reported in another related study in Akure, Nigeria (Olusi & Abe, 2014); the 0.0% in Port Harcourt, Nigeria (Okonko et al., 2019); the 4.8% reported in Ethiopia (Kassa et al., 2006); the 2.24% reported in Bamenda, Cameroon (Njunda et al., 2012) and 0.52% reported by Ssentongo et al. (2020). This discrepancy is most likely caused by the low prevalence of HIV (1.7%) in Bayelsa State, Nigeria (NAIIS, 2019).

According to a different study, there was no discernible statistical difference in malaria prevalence between people with HIV and those without HIV (Hochman & Kim, 2012; Sanyaolu et al., 2013). However, given that the study's findings showed that malaria diagnoses were 47.7% higher among HIV-positive people than in non-positive people (compared to 25.8%), there appears to be a connection between malaria susceptibility and HIV seropositivity. Several researchers have found the same (Ideymor, 2007; Hochman & Kim, 2012). Many HIV-infected people in Mozambique and South Africa also had malaria (Guyatt & Snow, 2001). Similarly, research in South-eastern Nigeria reported that 11.8% of asymptomatic HIV-positive patients also had co-infection (Fo, 2004). Overall co-infection prevalence was 19.0% in

adults, 12.0% in pregnant women, and 9.0% in children, according to Naing et al. (2006). According to a study in the Nigerian city of Ondo, pregnant HIV-positive individuals frequently contract malaria, with first-trimester cases having the highest prevalence (Olusi et al., 2019).

The participants' ages may also help to explain the low prevalence found. The only participants in this study were those who ranged in age from 8 to 72. Many studies have emphasized the age range as less susceptible to malaria and HIV infection. Infection with HIV and malaria is more common in people aged 21 to 40 than others (Saracino et al., 2013; Tay et al., 2015). This observation is similar to our findings, where HIV/Malaria co-infection rate decrease with an increase in age, from 6.0% for those within 21 – 40 years to 4.4% for those within 41 years and above. Sharma & Chauhan (2018) found the most significant number of HIV-positive individuals within the 30 – 49 age range. These findings are further buttressed by the studies of NACA (2012), Awoleye &Thron (2015a, b), Sherwal et al. (2015), and Enuma et al. (2022).

This observation with age corresponds with other studies. According to Dada et al. (2016), the prevalence was higher among people aged 20 to 49. Our findings differ from those of a study conducted in Calabar, Nigeria (John et al., 2020) and Jegede et al. (2017), in which increased HIV/malaria co-infection was noted among individuals under the age of 25. It also differs from several other studies (Amuta et al., 2012; Apinjoh et al., 2015; Ebai et al., 2016; I et al., 2018; Jemimah et al., 2019; Sandie et al., 2019; Ejike et al., 2020a, b; Okonko et al., 2021) which reported a higher prevalence in <25 years. Contrary to a discovery made in eastern sub-Saharan Africa (Cuadros et al., 2011a, b), where age was shown to be highly linked with HIV infection, the age difference in this study was not significantly associated (p= 0.76).

In comparison to female individuals, male participants showed a greater rate of HIV/malaria co-infection. Kublin et al. (2005), Tagoe and Boachie (2012), Onankpa et al. (2017), Ejike et al. (2020a, b), and John et al. all concur well with this observation (2020). Women are 50.0% more likely to get malaria than men, making gender a key risk factor in the frequency of both malaria and HIV infection (Jenkins et al., 2015). In this study, there was no evidence of a connection between sexual activity and HIV/malaria co-infection (p=0.54). This finding is in good agreement with John et al. (2020). Except for Oyeniran et al. (2022), which found that the prevalence of malaria was statistically significantly higher in female patients than in male patients, other studies found no statistically significant difference between the prevalence rate of malaria in females and males (Saracino et al., 2012; Tay et al., 2015). Only females were found to be coinfected with HIV and malaria in Port Harcourt, Nigeria, according to Okonko et al. (2021).

Several scientists disagreed, believing that females are more vulnerable to HIV infection. In agreement with the findings of the current study, Baume et al. (2009), Kimbi et al. (2013a), and Sabhapandit et al. (2017) discovered that men were more likely than women to have HIV. Our current conclusion conflicts with earlier research that claimed females were more likely than males to be coinfected with HIV and malaria (Njunda et al., 2012; Saracino et al., 2012; Kimbi et al., 2013b; Tay et al., 2015; Akinbo *et al*., 2016; Dada et al., 2016; Bassey & Izah, 2017; Obimakinde & Simon-Oke, 2017; Okokon *et al.,* 2017; Amadi et al., 2018; Bello & Ishaleku, 2018; Jemimah et al., 2019; Sandie et al., 2019; Dikwa *et al*., 2020; Oyeniran et al., 2022). This observation may be due to women cooking later in the day, which exposes them to more mosquito bites and the spread of malaria (Bassey & Izah, 2017). In Kano, Jegede et al. (2020) noted an unequal pattern and frequency between the sexes.

Although specific genders may prevail in research on malaria and co-infection, Abdulahi et al. (2009) warn that gender has no appreciable impact on malaria incidence. With malaria, females tend to dominate in incidence statistics. Its increased frequency in men has been linked to the fact that males in developing nations frequently engage in more job-related activities that regularly put them in contact with their outdoor surroundings long into the evenings when mosquitoes are more active (Obimakinde & Simon-Oke, 2017).

Maritally, a higher co-infection rate occurred among the married participants than among singles and divorced. Though, no significant association was found between HIV/Malaria co-infection and marital status (p= 0.47). This observation also contradicts that of Johnson and Way (2006), Msisha et al. (2008), Cuadros et al. (2011a, b), Ejike et al. (2020a, b) and John et al. (2020), which reported higher prevalence rates among singles/divorced than the married in their studies.

In terms of educational background, participants with tertiary education, followed by primary education and secondary education, had the highest prevalence of HIV/Malaria co-infection rate. This observation also contradicts that of Ejike et al. (2020a, b) and John et al. (2020), who reported a higher rate among primary education holders. Our observation also contradicts Alaofin et al. (2020), who found a strong association between educational attainment and decreased HIV/malaria co-infection rates in North Central Zone, Nigeria. In particular, HIV-malaria co-infection is more dominant among HIV-positive patients with secondary education and least frequent in participants with tertiary education (Alaofin et al., 2020). Similarly, our observation also contradicts that of Ugwu et al. (2013), Nyarko and Cobblah (2014)

and Ibrahim et al. (2022), which showed that malaria is more common among people with low literacy. In their investigations (Ugwu et al., 2013; Nyarko & Cobblah, 2014; Ibrahim et al., 2022), it was discovered that a lack of formal education raises the risk of malaria in the population under study. However, this study revealed no correlation between educational background and HIV/Malaria co-infection (p= 0.75), consistent with John et al. (2020)'s findings. This observation is inconsistent with several reports in Nigeria and sub-Saharan Africa that have associated HIV incidence and HIV/malaria co-infection with blue-collar workers who often have minimal formal education. These individuals have hesitated to accept their status and attend the associated clinics (Bhattacharya et al., 2011).

Regarding occupation, those who worked as civil employees had the highest risk of HIV/Malaria co-infection, followed by those who were unemployed, self-employed, and students, among other occupations. According to Ejike et al. (2020b) and Oyeniran et al. (2022), students had a greater rate of HIV/Malaria co-infection. This finding conflicts with Ejike et al. (2020a), who claimed business owners in Uyo, Nigeria, had a higher risk of HIV/Malaria co-infection. Contrary to the findings of Dalu et al. (2022) and Ibrahim et al. (2022), who reported that Farmers were marginally more likely to contract malaria than other occupational categories, with significant differences among them, the study also found no significant association between HIV/Malaria co-infection rate and occupations (p= 0.57).

Regarding CD4 counts, participants with CD4 levels of 500 or higher experienced a greater rate of HIV/Malaria co-infection (15.4%) than those with 350 to 499 cells/l (7.1%), whereas individuals with CD4 values of 200 and below experienced no HIV/Malaria co-infection. This observation cannot be the concomitant decline in CD4 among HIV-positive individuals. This finding conflicts with those made by John et al. (2020) in Calabar, Nigeria, Ejike et al. (2020a, b) in Uyo, and Tagoe and Boachie (2012) in old Cross River State, who showed that co-infection with HIV and malaria lowers CD4 T cell numbers in patients. The CD4 of the HIV patient who had malaria was high in this study, and this difference was significant (p = 0.02), as has been seen in several earlier investigations (Ojurongbe *et al.*, 2014; Tay *et al.,* 2015; Oyeniran et al., 2022). Some studies have also distinguished malaria from a low CD4 count in HIV-positive people (Tchinda et al., 2012; Ojurongbe et al., 2014). It differs slightly from Njunda et al. (2016), who found that the risk of malaria was increased with CD4 levels below 200 cells/mL.

Regarding viral loads, those with viral loads of <20 copies/ml had higher co-infection rates, while those with viral loads of 20–999 copies/ml and >1000 copies/ml had lower rates of 2.4% and 0.0%, respectively. Our study discovered that malaria-co-infected HIV participants have lower levels of HIV viral load and that malaria increases with decreasing viral load, in contrast to Kublin et al. (2005), Ejike et al. (2020a, b), and John et al. (2020). The rate of HIV/malaria co-infection did not significantly correlate with viral loads (p=0.39). This result may indicate a putative interaction between the virus and the malaria parasite. Also, in our study, parasite density rises when CD4 counts drop. These results are consistent with several related investigations and theories. For instance, Kwenti's comprehensive review from 2018 revealed that HIV infection is linked to increased malaria parasite density and malaria infection is linked to higher HIV viral load both in vivo and in vitro (Kwenti, 2018). Even though individuals who live in regions with persistent malaria transmission develop humoral and cell-mediated immunity to the parasite, it has been demonstrated that HIV-infected individuals can change this immunity, which may affect the frequency and course of malaria infection (Chaisavaneeyakorn et al., 2003). Hence, this could explain the relationship between viral load and malaria infection, where risk rises with viral load.

Antiretroviral treatment (ARV) combinations consisting of two nucleoside reverse transcriptase inhibitors (NRTIs) and a non-nucleoside reverse transcriptase inhibitor (NNRTI) or an integrase inhibitor (INSTI) are recommended by the World Health Organization (WHO, 2016) for the management of HIV (Oyeniran et al., 2022). Tenofovir, Lamivudine, and Dolutegravir users had a more significant percentage of participants with malaria parasitaemia (TLD). This result contradicts a study by Gennano et al. (2018), Sandie et al. (2019), and Oyeniran et al. (2022), which found that HIV-positive people who are not on ART have a higher prevalence of malaria than those who are.

Antiretroviral therapy (ART) and co-trimoxazole (CTX) treatment for malaria have been demonstrated to provide adequate protection against malaria in HIV-positive patients (Thera et al., 2005; Mermin et al., 2006; Flateau et al., 2011). Although none of the study participants took antimalarial medication, frequent use of these infection management strategies minimizes the likelihood of HIV-positive people developing malaria. According to Saracino et al. (2012), people with HIV receiving daily co-trimoxazole medication had a reduced risk of malaria of roughly 20.0%.

Though no statistically significant correlation between ART-related HIV/Malaria co-infection was discovered in this study, this could be due to the patient's immune systems being reformed by the medications they were given, demonstrating the effectiveness of ART, as well as the administration of co-trimoxazole as part of their chemotherapy, which is known to have some antimalarial components, reducing the incidence of malaria in HIV-infected people

(Oyeniran et al., 2022). This observation is consistent with research on CTX's ability to protect against HIV infection when combined with other preventive methods (Iroezindu et al., 2012).

In this study, there is no discernible difference between males and females in terms of the prevalence of the co-infection, and age is not a factor. This observation supports findings from a study conducted in Kano, North-West Nigeria (Jegede et al., 2017). However, it is at odds with findings from a study conducted in Jos, North-Central Nigeria (Uneke et al., 2005). In this study, risk variables for co-infection with HIV and malaria were also examined. However, only the CD4 count was found to be related to co-infection with malaria in HIV patients. Education level and occupation were additional variables that could confound or affect the association (Oyeniran et al., 2022); however, this study came to different conclusions.

5. Conclusion

In this study, the total frequency of HIV/malaria co-infection was reported to be 5.0%. A contributing factor to HIV/malaria co-infection was CD4 levels. Moreover, the viral load did not affect the co-infection of HIV and malaria. Men were more likely to contract HIV and malaria. HIV infection enhanced susceptibility to malaria, suggesting that HIV status may impact this tendency. Whereas their female counterparts showed a more significant propensity to HIV infection alone, males were more susceptible to HIV/Malaria co-infection. A substantial risk factor for HIV and malaria co-infection had a high CD4 level. HIV status did appear to affect a person's propensity to contract malaria, as HIV-positive individuals in Yenagoa, Nigeria, were shown to be more susceptible to the disease. We, therefore, urge that individuals living with HIV/AIDS be prioritized for any malaria intervention because of their vulnerability to malaria.

Compliance with ethical standards

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Disclosure of conflict of interest

The authors claim that there are no conflicting interests.

Statement of ethical approval

Nigeria's Federal Medical Centre in Yenagoa provided administrative approval for this investigation. According to all authors, the University of Port Harcourt Research Ethics committee evaluated and approved all experiments. The investigation is therefore carried out following the moral principles outlined in the 1964 Declaration of Helsinki.

Statement of informed consent

All authors state that everyone who participated in the study gave their informed, voluntary consent.

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