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Annals of Experimental Biology, 2023, 11 (2): 52-63
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ISSN:2348-1935

Triple Infections of HBV, HCV and Malaria *Plasmodium Falciparum* Among HIV-Infected Individuals in Yenagoa, Bayelsa State, Nigeria

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Received: *23 March, 2023, Manuscript no. aeb-23-92528;* ***Editor assigned:*** *25 March, 2023, Pre QC no. aeb-23-92528 (PQ);* ***Reviewed:*** *27 March, 2023, QC no. aeb-23-92528 (Q);* ***Revised:*** *30 March, 2023, Manuscript no. aeb-23-92528 (R),* ***Published:*** *05 April, 2023*

ABSTRACT

Infectious diseases continue to remain life-threatening and a significant public health problem globally. Patients with HIV frequently have concomitant HBV, HCV, and malaria infections; thus, this study was undertaken to describe the prevalence of HBV, HCV, and Malaria triple infection with HIV among patients presenting at the Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria. In this study, 104 HIV-positive patients were recruited and evaluated for the presence of HBsAg, HCV, and Plasmodium falciparum with HBsAg rapid strips, anti-HCV antibodies ELISA kit (Dia. Pro), and SD Bioline RDT, following the respective manufacturer's instructions. The triple infection rate was 1.0% for HIV/HBV/HCV/Plasmodium falciparum. Other co-infections were 1.9% for HIV/HCV/Plasmodium falciparum, 2.9% for HIV/HBV/Plasmodium falciparum, and 1.9% for HIV/HBV/HCV, respectively. A higher HIV/HBV/HCV/Plasmodium falciparum triple infection occurred in the age group 21years-40 years (2.0%), females (1.3%), being single (2.3%), tertiary education holders (2.4%), students (4.3%), CD4 counts>500 cells/µl (4.0%) and Viral Load (VL)<20 copies/ml (2.0%). Higher HIV/HBV/HCV triple infections occurred in the age group>41 years (2.2%), males (3.5%), being single (2.3%), tertiary education holders (4.8%) and students (4.3%), having CD4 count 350 Cells/µl- 499 Cells/µl (7.1%), viral load 20 copies/ml-999 copies/ml (2.1%) and being on TLD ART (1.9%). Higher HIV/HBV/MPF triple infections occurred in the age group 21 years-40 years (3.9%), males (3.5%), being married (3.6%), tertiary education holders (4.8%) and students (8.7%), having CD4 count>500 cells/µl (7.7%), viral load<20 copies/ml (3.8%) and being on TLD ART (2.9%). Higher HIV/HCV/MPF triple infections occurred in the age group 21 years-40 years (3.9%), females (2.7%), being single (4.7%), tertiary education holders (4.8%) and students (8.7%), having CD4 count>500 cells/µl (4.0%), viral load <20 copies/ml (2.0%) and being on TLD ART (1.9%). None of the sociodemographic and clinical variables was significantly associated (p>0.05) with triple infections. The present study has further confirmed the low occurrence (1.0%) of HIV/HBV/Plasmodium falciparum among HIV-infected individuals in Yenagoa, Nigeria. Ages 21 years-40 years, females, being single, tertiary education holders, and students were more prone to triple infections. The concurrency of HIV/HCV/HBV and Malaria exists in Yenagoa, Nigeria. Therefore, it is recommended to perform routine screening of HIV-infected patients for simultaneous infection with HBV, HCV, and Malaria.

Keywords: Co-infections, HIV/HBV, HIV/HCV, HIV/*Plasmodium falciparum*, HIV/HBV/HCV/*Plasmodium falciparum*, Triple infections

INTRODUCTION

Malaria remains a significant health threat worldwide. Infectious diseases remain life-threatening and a significant public health problem globally [1]. Endemic regions for malaria are endemic to other infectious diseases that might affect the malaria infection [2,3]. Examples of such a common endemic infection sharing the same territory with malaria are Hepatitis B Virus (HBV)

and Hepatitis C (HCV) [3-6].

Worldwide, HBV and HCV represent significant public health problems; around 300 million people are infected with HBV and HCV [7-9]. HBV and HCV infections are responsible for the majority of cases of chronic liver diseases, namely liver cirrhosis and hepatocellular carcinoma [9,10]. HBV and HCV co-infection is common among people living with Human Immunodeficiency Virus (HIV) infection (PLWH) because of common routes of transmission such as the exchange of blood or other body fluids during Intravenous Drug Use (IVDU), sexual contact, or mother-to-child-transmission-during the perinatal period [11-13]. If undiagnosed and untreated, this co-infection accelerates liver deterioration and increases morbidity and mortality in PLWH [13,14].

HIV remains a significant public health threat, with an additional risk of HBV and HCV co-infection [13]. Based on the report of the Joint United Nations Programme on HIV/ AIDS 2019 and the World Health Organization (WHO, 2017), approximately 38 million people have been diagnosed with HIV, 257 million with HBV, and 71 million with HCV globally at the end of 2020 [13,15,16]. Therapeutic advancements have greatly aided the eradication of the HBV, HCV, and HIV epidemics during the past few decades. Strategies have been put in place by the WHO and the Joint United Nations Programme on HIV/AIDS to encourage the global eradication of these viruses by 2030 [13,17,18]. Among other factors, the success of these strategies relies upon the testing and diagnosis of at least 90% of all persons living with HBV, HCV, and HIV infections as a necessary first step towards engagement in care and treatment [13,19,20].

To the best of our knowledge, there is a dearth of literature on the prevalence of HBV/HCV/*Plasmodium falciparum* triple infection among HIV-infected individuals in Bayelsa State, Nigeria. Studies on the triple infections of HBV, HCV, and *Plasmodium falciparum* among patients with HIV are limited in Bayelsa State, Nigeria. Therefore, this study was created to ascertain the prevalence of triple infections with HBV, HCV, and *Plasmodium falciparum* in HIV-positive patients.

MATERIALS AND METHODS

Study area

The study was conducted at the Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria. This hospital is one of the main treatment facilities for HIV-infected patients in Bayelsa State, Southern Nigeria.

Study design

A hospital-based cross-sectional study design was adopted for the present study, which seeks to determine HBV, HCV, and *Plasmodium falciparum* triple infections among HIV-infected individuals attending Federal Medical Centre, Yenagoa, Bayelsa State, Nigeria.

Ethics statement

Administrative approval for this study was obtained from the management of the Federal Medical Centre, Yenagoa, Nigeria. The University of Port Harcourt Research Ethics Committee reviewed the work for ethical issues and approved the standards for research involving human beings. Before samples were taken and processed, everyone who participated gave informed consent.

Study population

We recruited 104 HIV-infected individuals attending the HIV outpatient clinic of Federal Medical Centre, Yenagoa, Nigeria, who willingly gave informed consent and volunteered to examine their blood samples. The study entailed screening for co-infections, clinical evaluation, and recording of demographic information such as the age of the participants, sex, marital status, educational background, occupation, and use of art.

Sample collection

The method of sample collection employed was the vein puncture technique. About 3 ml of venipuncture blood was collected in EDTA BA Vacutainer TM anti-coagulant tubes (BD, Franklin Lakes, USA), labeled with each patient's details. Plasma specimens were separated by centrifugation at 3000 rpm (revolution per minute) for 5 minutes. The plasma was stored at -20°C and used for laboratory analyses.

Serological analysis

Blood samples were taken and examined at the Virus & Genomics Research Unit, Department of Microbiology, University of Port Harcourt, for HBsAg, HCV, and Plasmodium falciparum antigen using appropriate test kits. Laboratory testing was carried out according to the manufacturer's instructions, and all tests were run using quality controls according to standard operating procedures.

Data analysis

SPSS version 20.0 was used to analyze the data (SPSS Inc. Chicago, IL, USA). Using Pearson's chi-square (X2) test or Fisher's exact test, as applicable, the prevalence of co-infections among HIV-infected individuals was compared to CD4+ T cell count, viral loads, sociodemographic factors, and the use of ART. A 5% significance level was used to establish the statistical significance for each analysis.

RESULTS

Study population characteristics

Characteristics of the study group are highlighted in Table 1.

Overall prevalence of triple infections

Figure 1 represents the results obtained from the study. A total HIV seropositivity of 100% was obtained for all samples, reconfirming the HIV status of the study participants. Further analysis for HBsAg, anti-HCV antibodies, and malaria *Plasmodium falciparum* revealed 2.9% for HIV/HBV/*Plasmodium falciparum*, 1.9% for HIV/HBV/HCV, 1.9% for HIV/HCV/*Plasmodium falciparum*, and 1.0% for HIV/HBV/HCV/*Plasmodium falciparum*, respectively.

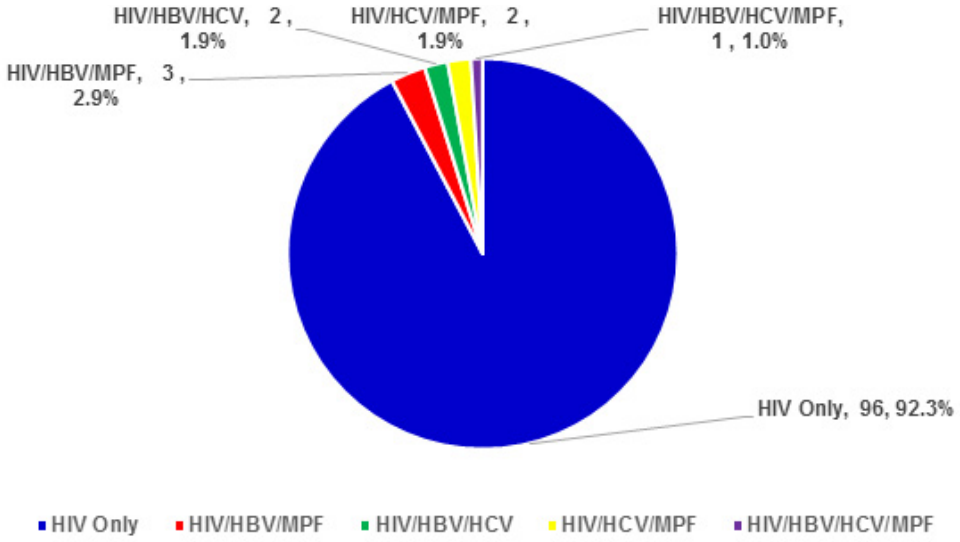

Figure 1. Triple infections of HBV/HCV/*Plasmodium falciparum*

Age-specific HBV/HCV/Plasmodium falciparum triple infections

Higher HBV/HCV/*Plasmodium falciparum* triple infections occurred among age groups 21years–40 years (2.0%) than other age groups with 0.0% (Figure 2). These differences were not statistically associated (p=0.59).

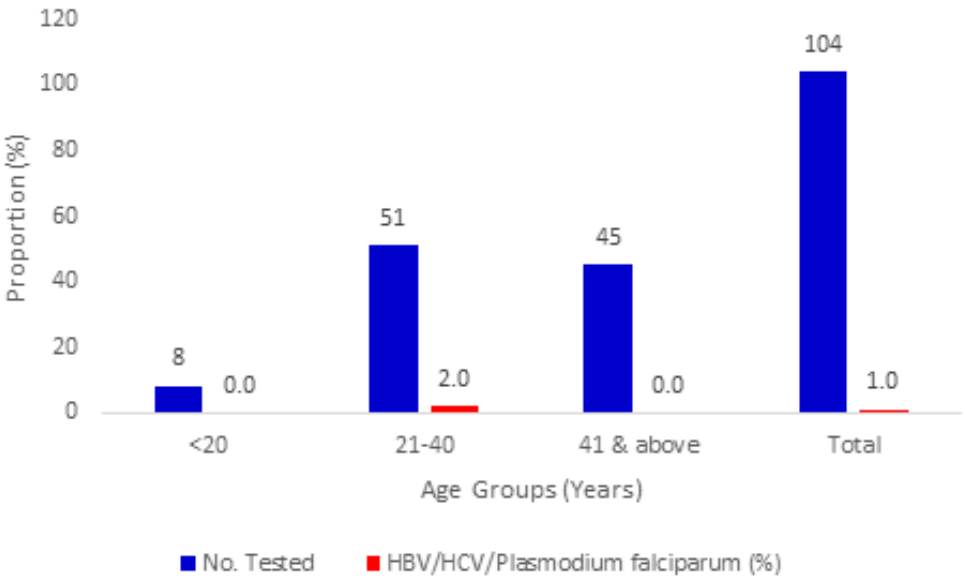

Figure 2. HBV/HCV/*Plasmodium falciparum* triple infections in relation to age

Sex-specific HBV/HCV/Plasmodium falciparum triple infections

Higher HBV/HCV/Plasmodium falciparum triple infections were observed among females (1.3%) than in males (0.0%) (Figure 3). No significant association existed between HBV/HCV/*Plasmodium falciparum* triple infections and sex (p=0.53).

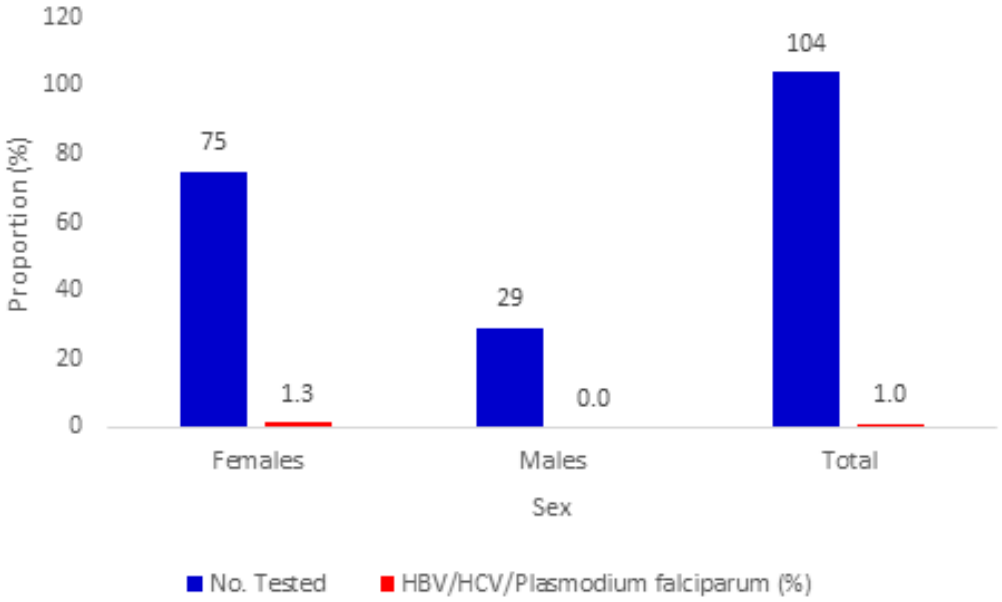

Figure 3. HBV/HCV/*Plasmodium falciparum* Triple Infections in relation to Sex

Marital Status-specific HBV/HCV/Plasmodium falciparum triple infections

Higher HBV/HCV/*Plasmodium falciparum* triple infections occurred among singles (2.3%) than the married (0.0%) and divorced (0.0%) (Figure 4). No significant association existed between HBV/HCV/*Plasmodium falciparum* triple infections and marital status (p=0.49).

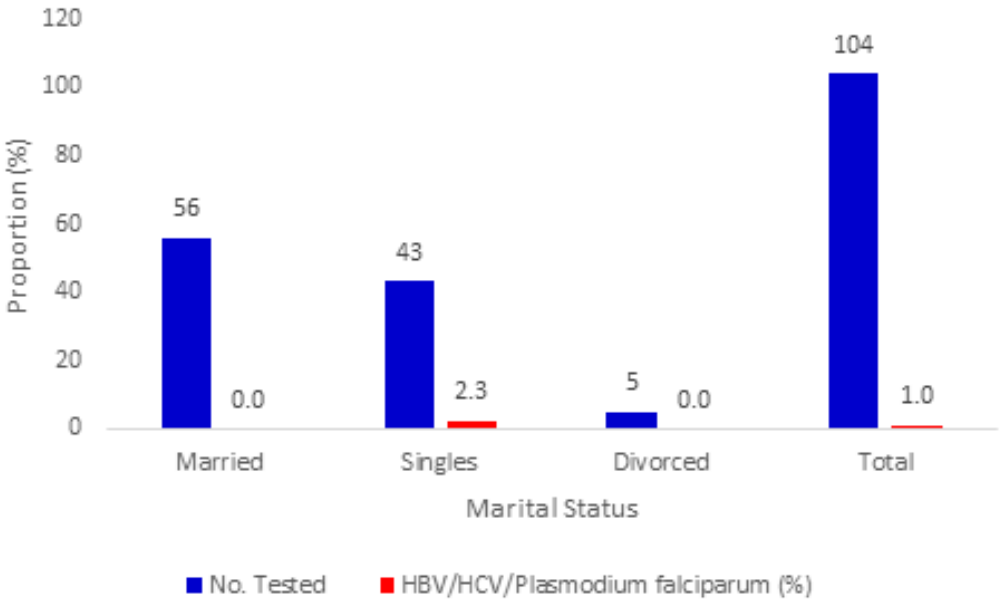

Figure 4. HBV/HCV/*Plasmodium falciparum* Triple Infections in relation to marital status

Educational Background-specific HBV/HCV/Plasmodium falciparum triple infections

Higher HBV/HCV/*Plasmodium falciparum* triple infections were observed among those with tertiary educational background (2.4%) than those with secondary education (0.0%) and primary education with 0.0% (Figure 5). No significant association was found between HBV/HCV/*Plasmodium falciparum* triple infections and educational background (p=0.68).

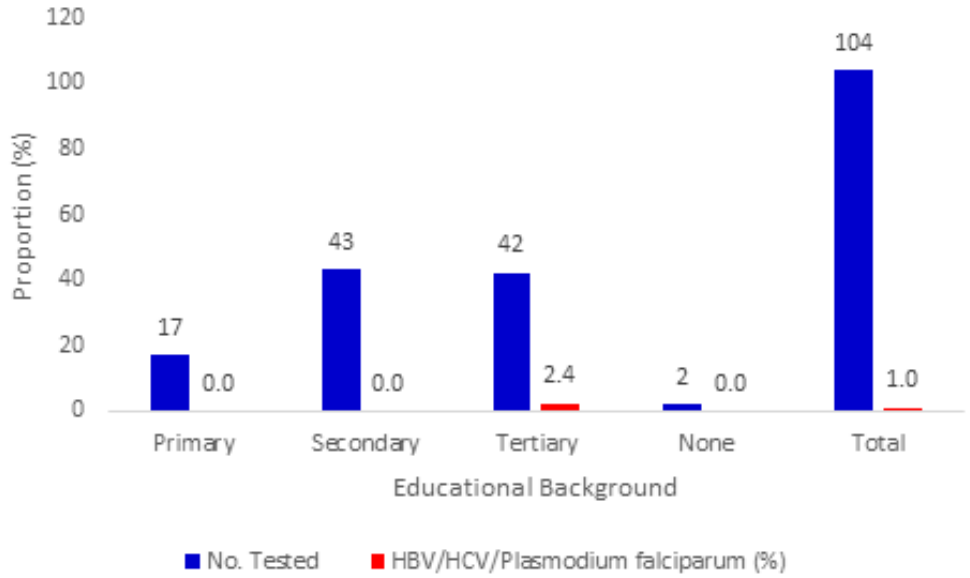

Figure 5. HBV/HCV/*Plasmodium falciparum* Triple Infections in relation to Educational Background

Occupation-specific HBV/HCV/Plasmodium falciparum triple infections

Higher HBV/HCV/*Plasmodium falciparum* triple infections were observed among students (4.3%) than in other occupations with 0.0% (Figure 6). No significant association existed between HBV/HCV/*Plasmodium falciparum* triple infections and occupations (p=0.61).

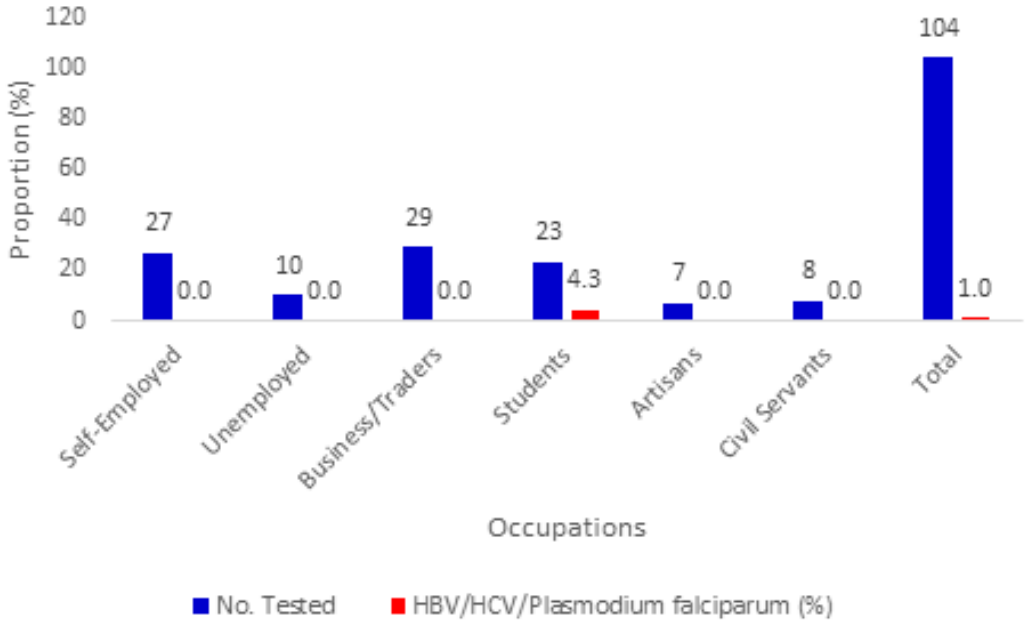

Figure 6. HBV/HCV/*Plasmodium falciparum* triple infections in relation to occupations

CD4 counts-related specific HBV/HCV/Plasmodium falciparum triple infections

In terms of CD4 counts, higher HBV/HCV/*Plasmodium falciparum* triple infections (4.0%) were observed for participants with CD4 counts>500 cells/µl than <200, 200-349 and 350-499 cells/µl had the least, 0.0% (Figure 7). No significant association existed between HBV/HCV/*Plasmodium falciparum* triple infections and CD4 counts (p=0.39).

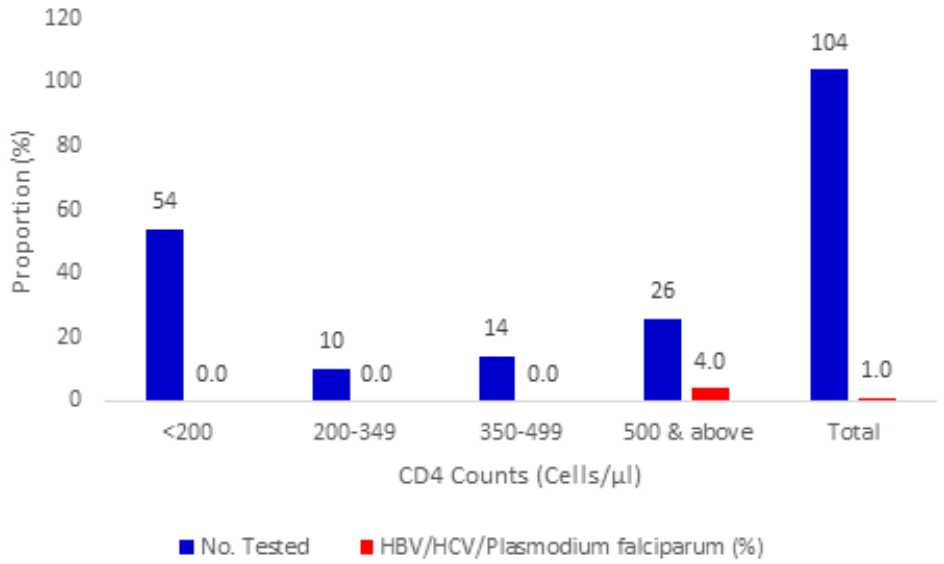

Figure 7. HBV/HCV/*Plasmodium falciparum* Triple Infections in relation to CD4 Counts

Viral loads-related specific HBV/HCV/*Plasmodium falciparum* triple infections

In terms of viral loads, higher HBV/HCV/*Plasmodium falciparum* triple infections (0.0%) were recorded for participants that had<20 copies/ml than those with 20-999 copies/ml and>1000 copies/ml with 0.0% (Figure 8). No significant association existed between HBV/HCV/*Plasmodium falciparum* triple infections and viral loads (p=0.62).

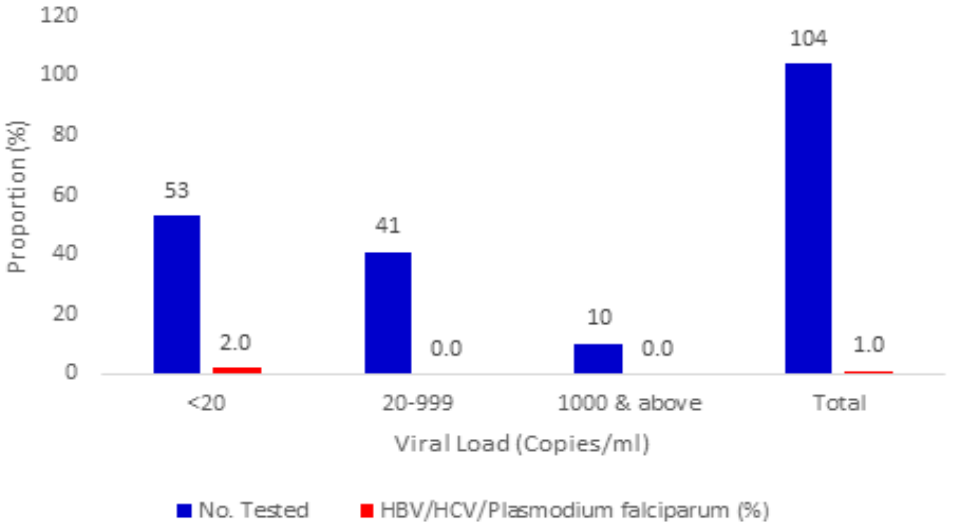

Figure 8. HBV/HCV/*Plasmodium falciparum* Triple Infections in relation to Viral Loads

Sociodemographic Characteristics and other triple infections

Higher HIV/HBV/HCV triple infections occurred in the age group >41 years (2.2%), males (3.5%), being single (2.3%), tertiary education holders (4.8%) and students (4.3%), having CD4 count 350 Cells/µl-499 Cells/µl (7.1%), viral load 20-999 copies/ml (2.1%) and being on Tenofovir, Lamivudine, and raltegravir (TLD) ART (1.9%) (Table 1).

Higher HIV/HBV/ Malaria *Plasmodium falciparum* triple infections occurred in the age group 21 years-40 years (3.9%), males (3.5%), being married (3.6%), tertiary education holders (4.8%) and students (8.7%), having CD4 count >500 cells/µl (7.7%), viral load <20 copies/ml (3.8%) and being on Tenofovir, Lamivudine, and Dolutegravir (TLD) ART (2.9%), as in Table 1.

Higher HIV/HCV/Malaria *Plasmodium falciparum* triple infections occurred in the age group 21-40 years (3.9%), females (2.7%), being single (4.7%), tertiary education holders (4.8%) and students (8.7%), having CD4 count >500 cells/µl (4.0%), viral load <20 copies/ml (2.0%) and being on Tenofovir, Lamivudine, and dolutegravir (TLD) ART (1.9%) as in Table 1.

Table 1. Patients Characteristics

Variables	Categories	No. Tested	HIV/HBV/HCV (%)	HIV/HBV/MPF (%)	HIV/HCV/ MPF (%)	HIV/HBV/HC/ MPF (%)	Chi-Square analysis
Age groups (Years)	20-Aug	8	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	P = 0.59
	21-40	51	1(2.0)	2 (3.9)	2 (3.9)	1(2.0)	
	41 & above	45	1 (2.2)	1 (2.2)	0 (0.0)	0 (0.0)	
Sex	Females	75	1(1.3)	2 (2.7)	2 (2.7)	1(1.3)	P = 0.53
	Males	29	1 (3.5)	1 (3.5)	0 (0.0)	0 (0.0)	
Marital Status	Singles	43	1(2.3)	1(2.3)	2 (4.7)	1(2.3)	P = 0.49
	Married	56	1 (1.8)	2 (3.6)	0 (0.0)	0 (0.0)	
	Divorced	5	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Educational Background	Primary	17	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	P = 0.68
	Secondary	43	0 (0.0)	1(2.3)	0 (0.0)	0 (0.0)	
	Tertiary	42	2 (4.8)	2 (4.8)	2 (4.8)	1(2.4)	
	None	2	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Occupations	Self-Employed	27	1 (3.7)	0 (0.0)	0 (0.0)	0 (0.0)	P = 0.61
	Unemployed	10	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	Business/ Trader	29	1 (3.5)	1 (3.5)	0 (0.0)	0 (0.0)	
	Students	23	1(4.3)	2 (8.7)	2 (8.7)	1(4.3)	
	Artisans	7	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	Civil Servants	8	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
CD4 Counts (Cells/ µl)	<200	54	1(1.9)	1(1.9)	0 (0.0)	0 (0.0)	P = 0.39
	200-349	10	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
	350-499	14	1(7.1)	0 (0.0)	0 (0.0)	0 (0.0)	
	500 & above	26	0 (0.0)	2(7.7)	1 (4.0)	1(4.0)	
Viral Loads (Copies/ml)	<20	53	1(2.0)	2 (3.8)	1(2.0)	1(2.0)	P = 0.62
	20-999	41	1 (2.4)	1 (2.4)	0 (0.0)	0 (0.0)	
	1000 & above	10	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
ART Drugs	TLD	103	2 (1.9)	3 (2.9)	2 (1.9)	1(0.9)	
	ABC/BTC/ EFC	1	0 (0.0)	0 (0.0)	0 (0.0)	0 (0.0)	
Total		104	2(1.9)	3(2.9)	2(1.9)	1 (1.0)	

HBV = Hepatitis B Virus, HCV = Hepatitis C Virus, HIV = Human Immunodeficiency Virus, MPF = Malaria *Plasmodium falciparum*

DISCUSSION

HIV and malaria have similar risk factors, and HIV/HBV/HCV co-infection speeds up the development of AIDS, which results in millions of deaths annually throughout the world [21]. The study shows interactions between HBV, HCV, and malaria *Plasmodium falciparum* infections among HIV-infected people in Yenagoa, Bayelsa State, Nigeria, with some developing co-infections. As far as we know, no studies have been conducted in Yenagoa or the South-South region that considered these four illnesses simultaneously. Unfortunately, epidemiological information on HIV/HBV, HIV/HCV, and HIV/HBV/HCV co-infections among HIV patients is scarce and inconsistent domestically and internationally [13].

The study presents the fundamental demographic and clinical traits of co-infections with HBV, HCV, and malaria (*Plasmodium falciparum*) in HIV-infected patients. This study's total prevalence of co-infection with HIV and HBV/HCV/malaria (*Plasmodium falciparum*) was 1.0%. HIV mono-infection was 92.3% among them, while the co-infection rates for HIV/HBV/malaria, HIV/HCV/ malaria, and HIV/HBV/HCV were 2.9%, 1.9%, and 1.9%, respectively. The results of our study agreed with those of other research from Nigeria and elsewhere.

The 1.0% HBV/HCV/malaria *Plasmodium falciparum* prevalence reported in this study is comparable to the 1.9% HIV/HBV/HCV and malaria co-infection reported by Mohammed in Gedarif, Eastern Sudan [16]. In our analysis, triple infections with HIV, HBV, HCV, and *Plasmodium falciparum* only occurred in those aged 21 to 40 (2.0%), women (1.3%), singles (2.3%), those with university education (2.4%), and students (4.3%). As revealed in Gedarif, Eastern Sudan, none of these sociodemographic factors was substantially linked ($p>0.05$) with triple infections.

The 2.9% reported for triple infections with HIV, HBV, and *Plasmodium falciparum* in this study is higher than in previous studies. Kogi State had a 0.5% HBV/*Plasmodium falciparum* co-infection, according to Omatola & Okolo [22]. 1.0% co-infection between malaria and HBV was observed by Adeleke, and 2.2% was reported by Afolabi and Bakare [23,24]. However, the 5.0% Okonko recorded in a previous study in Port Harcourt is lower than it [25].

This study's 2.9% reported rate of triple infections with HIV, HBV, and *Plasmodium falciparum* is greater than the 0.0% reported

by Okonko in Port Harcourt, Nigeria [26]. It also did not match the conclusions of other earlier investigations. According to Helegbe, Ghana has a 0.7% prevalence of triple infections with HIV, HBV, and *Plasmodium falciparum* malaria [1]. The prevalence rates of 3.3%, 4.3%, and 6.0% were previously reported in various places in Nigeria and the Gambia, respectively, they were higher than the figure recorded in the current study [27-29]. That varies from Anabire results, who reported that 1.9% of patients had *P. falciparum*/HBV co-infection and similarly recorded opposing values in their study [30,31].

In terms of sociodemographic factors linked to HIV/HBV/Malaria *Plasmodium falciparum* triple infections, males (3.5%), married individuals (3.6%), those with university education (4.8%), and students (8.7%) all experienced greater rates. As revealed by Mohammed in Gedarif, Eastern Sudan, none of these sociodemographic factors was substantially linked ($p > 0.05$) with triple infections [9].

Of these triple infections, HIV/HBV/HCV was 1.9%. This value is less than the 16.9% recorded for triple infection with HBV, HCV, and HIV in Abeokuta, Ogun State, Nigeria [32]. Several seroprevalences of HIV/HBV/HCV infections were reported in Nigeria in earlier research. According to Forbi, 7.2% of people worldwide have HIV, HBV, or HCV [33]. In Central Nigeria, Balogun reported a seroprevalence of 3.9% for HIV/HBV/HCV, Okeke recorded a seroprevalence of 6.5%, and Oti et al. (2021) reported a seroprevalence of 2.8% [34,35].

In the same study area, Aaron and Cookey reported values of 0.0% and 0.0%, respectively (Port Harcourt, Nigeria) [36,37]. Moreover, the 1.9% reported here exceeds the 1.0% frequency in Central Nigeria that Pennap reported [38]. It is also greater than the 1.3% and 0.5% found in Edo-Ekiti and Benin, respectively [39,40]. That is greater than the 0.34% reported for triple infection with HIV, HBV, and HCV by Bhattarai [41]. In contrast to the 1.83% reported by Agarwal, the seroprevalence of 1.9% found here is favorable [42].

In other places, rates of HIV, HBV, and HCV triple infection of 19.1% and 10.4%, respectively, were observed in China and Myanmar [43]. According to Gupta and Singh, North India has a triple infection prevalence of 5.32% and 2.43%, respectively [44]. According to Musyoki , the prevalence of HIV/HBV/HCV infections in South Africa was 29.4% [45]. According to Lonita, 4.4% and 19.0% of Nepal's population are triply infected with HIV, HBV, and HCV [46]. At Kumasi, Ghana, Boateng found a prevalence of co-infections with HIV, HBV, and HCV of 18.0% [47]. According to Pappoe, Ghana had a 6.1%, 0.5%, and 0.0% prevalence of HIV, HBV, and HCV co-infections, respectively [48]. Similarly, the combined HIV/HBV/HCV prevalence reported by Shrestha in a systematic review study of Nepal from 1990 to 2020 was 1.3% [49]. In Eastern Nepal, 2.53% of cases of HIV/HBV/HCV triple infections were reported by Shrestha in 2022.

It is essential to note the increased prevalence of HBV and HCV dual infection in this study compared to prior studies [35]. Furthermore, these studies have shown that triple HIV/HBV/HCV infections or dual HIV/HBV/HCV infections are the most prevalent. However, the incidence of these infections depends on risk categories, the type of exposure involved, and geographic locations [43, 50-52].

In terms of sociodemographic factors, greater rates of HIV/HBV/HCV triple infections occurred in people over the age of 41 (2.2%), in men (3.5%), in singles (2.3%), in those with university education (4.8%), and in students (4.3%). None of these sociodemographic factors showed a meaningful correlation ($p>0.05$). This result contrasts with that of studies by Shrestha, which found that people under 35 were more at risk of co-infection, and Choy, which found that people in their 30s, 40s, and 50s had considerably higher rates of co-infection [13,53]. The current finding conflicts with that of Oti, who claimed that only educational status was statistically associated with HIV/HCV co-infection in Central Nigeria [35].

Plasmodium spp. and HCV are known to infect liver cells; hence, given that the hepatitis C and malaria epidemics overlap in some parts of the world, it is conceivable that they might infect and reproduce in the same cell. Moreover, it is conceivable that these two illnesses could co-infect, in which case one pathogen could influence the other's severity to rise or fall and vice versa. Furthermore, despite substantial research on HCV attachment and entrance due to the virus's rising prevalence worldwide, more research needs to be done on plasmodium entry into host hepatocytes. Investigating the co-infection of the three diseases was imperative since it would aid in creating novel treatments and testing equipment. In Yenagoa, Bayelsa State, Nigeria, the study found 1.9% triple infections with HIV, HCV, and *Plasmodium falciparum*.

In contrast to the 10.9% reported by Asaga in Abuja, Central Nigeria, this study's 1.9% reported rate of triple infections with HIV, HCV, and *Plasmodium falciparum* is lower. Sociodemographic indices revealed numerous variations in prevalence across the various groupings. HIV/HCV/malaria *Plasmodium falciparum* triple infections were more common in people aged 21years to 40 years (3.9%), in women (2.7%), in singles (4.7%), in those with tertiary education (4.8%), and in students (8.7%). As revealed by Mohammed in Gedarif, Eastern Sudan, none of these sociodemographic factors was substantially linked ($p>0.05$) with triple infections [9]. This observation disputes the assertion made by Ouwe-Missi-Oukem-Boyer that age is a significant confounding factor in their setting. Multivariate analysis, on the other hand, suggests that *P. falciparum* and HCV interact at the hepatic level, with *P. falciparum* emerging more slowly in HCV chronic carriers [54]. According to Asaga, in HIV-infected people, co-infection rates for malaria and HCV were 8.7% and 11.2%, respectively.

Contrary to a study by Asaga, which found higher rates in the younger age range of 15 years to 25 years in Abuja, Nigeria, the higher rates of HIV/HCV/*Plasmodium falciparum* triple infections were recorded in older age groups >41 years (2.2%). HCV's tendency could explain the discrepancy in the results to self-limit as a child gets older and eventually acquires the status of a chronic carrier. Also, this observation represents a complete departure from a related study in Egypt, where the prevalence ranged from 0.2% to 5.0% [55].

Asaga study, which found higher rates in married women than singles and agrees with our study in that 0.0% prevalence was also reported for participants who had recently divorced, contradicts the higher rates of HIV/HCV/*Plasmodium falciparum* triple infections reported in singles than other marital groups. The results of Todd, who found that participants with HCV co-infection were less likely

to be married, are consistent with our data [56]. In the current study, lifestyle, social activities, and awareness may be the primary deductive reasoning factors contributing to this [57-59].

In this study, triple infections with HIV, HCV, and Plasmodium falciparum only occurred in those with tertiary education. Asaga showed higher rates in women who attended Islamic Quranic schools (20%) compared to postsecondary education level (18.6%). This observation is in contrast to their findings. This finding might be explained by a person's lifestyle, social interactions, and awareness. The results of this study showed complete agreement with the claim made by Oni that greater levels of education increase the likelihood of sexual adventures, which frequently involve several partners [60]. The results of this investigation showed a complete divergence from those of the Asaga study. However, it contrasts with the findings of Todd. However, the results of Todd showed that people with HCV co-infection had a lower likelihood of having a tertiary education [56].

In addition, our findings indicate that females are more likely than males to have co-infections with HIV/HCV/Plasmodium falciparum and HIV/HBV/HCV/*Plasmodium falciparum*. The study by Shrestha, which indicated a higher likelihood among males than females, did not support this finding [13]. In contrast, the males were more likely to be coinfected in the study by Lonita [46]. This observation could be a result of female sexual promiscuity. Age and gender of the male were risk variables for co-infection [3]. It is necessary to determine the precise cause of these differences from other prospective cohort studies.

To the best of our knowledge, there is no information on the relationship between CD4+ T cell count, viral load, and co-infections with HIV, HBV, HCV, and *Plasmodium falciparum* in Bayelsa State, Nigeria. Only HIV-infected patients with CD4 counts > 500 cells/l (4.0%) and viral loads (VL) 20 copies/ml (2.0%) had a triple infection. Increased HIV/HBV/HCV triple infections were seen in people with CD4 counts between 350 and 499 cells/l (7.1%), viral loads between 20 copies/ml and 999 copies/ml (2.1%), and TLD ART use (1.9%). Having a CD4 count>500 cells/l (7.7%), a viral load of<20 copies/ml (3.8%), and being on Tenofovir, Lamivudine, and Dolutegravir (TLD) ART (2.9%) were also associated with an increased risk of HIV/HBV/MPF triple infections.

Additionally, having a CD4 count >500 cells/l (4.0%), a viral load of <20 copies/ml (2.0%), and being on Tenofovir, Lamivudine, and Dolutegravir (TLD) ART (1.9%) were associated with greater HIV/HCV/Malaria *Plasmodium falciparum* triple infections. In support of Kakisingi who noted that none of the CD4 count and viral load tested in Lubumbashi, DR Congo, exhibited any statistically significant difference, none of these clinical variables was significantly linked ($p > 0.05$) with triple infections [61]. Our findings go counter to those of Ebong, who claimed that correlations between the CD4 count and the kind of illness (*Plasmodium*) or even co-infection (HIV/HCV) had existed [21]. This finding conflicts with research by Bhattarai and Shrestha, which found co-infection was less common in HIV patients with CD4 cells above 200 cells/mm^3 [13]. However, a CD4 count under 200 cells/l still carries a substantial risk for opportunistic infections [62,63]. According to George and Wang, the declining CD4 cell count is a sign of HIV progression and immunological dysfunction, as well as co-infections and various opportunistic infections [13,64,65]. Nevertheless, this study's scenario was the opposite. However, research carried out in regions where HIV and malaria are highly endemic discovered a very high viral load and a meagre CD4 count in related individuals [66,67].

These pathogens' overlap is a significant health concern [35,68]. However, more research is required on the seroprevalence of HBV, HCV, and malaria (*Plasmodium falciparum*) among HIV-positive patients in Nigeria. When compared to the WHO norm, we discovered that the overlapping infections of HIV/HBV/*Plasmodium falciparum*, HIV/HCV/*Plasmodium falciparum*, HIV/HBV/HCV, and HIV/HBV/HCV/*Plasmodium falciparum* were 2.9%, 1.9%, 1.9%, and 1.0%, respectively [35]. Chronic HCV carriers' interactions with malaria parasites may prevent the latter from spreading, which may aid in developing novel malaria treatment strategies [3]. The study also urges establishing a routine HBV, HCV, and Plasmodium screening program employing malaria Rapid Diagnostic Tests (RDT) to identify the preventative actions that must be performed in the treatment of HIV-infected people [69].

CONCLUSION

According to this study, the rates of triple infection for HIV/HBV/HCV/*Plasmodium falciparum* were 1.0%, 1.9%, 2.9%, and 1.9%, respectively. This study reveals for the first time that Yenagoa, Bayelsa State, Nigeria, has concurrent HIV/HCV/HBV and malaria cases. Hence, systematic testing for co-infection with HIV, HBV, HCV, and malaria in HIV-infected individuals should be adopted. It is necessary to do additional research on clinical patterns and risk variables to comprehend how HIV/HCV/HBV and malaria co-infection emerged in the study area.

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