

Prevalence, Seasonality, and Risk Factors of Malaria and Some Arboviral Infections and Co-Infections in Nigeria

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Abstract Introduction: This study aimed to investigate the prevalence and risk factors of malaria and arboviral infections in Nigeria. **Method:** Molecular techniques were used to test 1020 febrile patients in 10 hospitals in Lagos, Ogun, and FCT between 2022 and 2023. Blood samples were collected from study participants and tested for malaria using rapid diagnostics tests, microscopy, and polymerase chain reaction (PCR). In addition, the samples were tested for arboviruses using PCR. Statistical analysis was performed using Stata version 17, at a 5% level of significance. **Result:** Zika had the highest prevalence among study participants (23.3%) followed by malaria (12%), West Nile (5.8%), Chikungunya (5.7%), Dengue (3.3%), and yellow fever (2%). There were sixteen combinations of co-infection from this study, Chikungunya-Zika co-infection had the highest prevalence (4.6%) followed by Zika-West Nile co-infection (3.3%) and Chikungunya-West Nile co-infection (3.1%). Travel history was significantly associated with the prevalence of

malaria ($X^2=6.52$, $P\text{-value}=0.001$) and DenV ($X^2=4.91$, $P\text{-value}=0.027$). Seasonality was also significantly associated with malaria ($X^2=10.28$, $P\text{-value}=0.001$), DenV ($X^2=7.67$, $P\text{-value}=0.006$), and ZikV ($X^2=6.54$, $P\text{-value}=0.011$). State of residence was significantly associated with all vector-borne diseases ($P<.05$). Occupation was also found to be associated with malaria ($X^2=13.27$, $P\text{-value}=0.021$), ChikV ($X^2=11.78$, $P\text{-value}=0.038$), YFV ($X^2=21.03$, $P\text{-value}=0.001$), ZikV ($X^2=17.31$, $P\text{-value}=0.004$). **Conclusion:** This study reveals a higher prevalence of Zika than malaria and a significant prevalence of the investigated arbovirus infections and coinfections. These findings may inform surveillance and response to potential outbreaks of arbovirus disease in Nigeria.

Keywords Malaria, Arboviral Infection, Vector-borne Disease

1. Introduction

The high endemicity of malaria in Nigeria makes it one of the most incriminated etiology of febrile illnesses that is often misdiagnosed and presumptively managed [1]. However, studies have confirmed the cases of arboviral infections in febrile patients regardless of the presence of malaria infection [2], [3]. Arboviruses are arthropod-borne viruses that belong to several virus families, including *Flaviviridae*, *Togaviridae*, and *Bunyaviridae* [4]. The common arboviral diseases across the globe are Dengue, West Nile, Chikungunya, Yellow Fever, and Zika. The symptoms of these diseases include fever, rash, hemorrhage, encephalitis, myalgia, among others [4]. Diagnosis of these diseases can be performed using molecular and serological techniques [5]. This group of diseases is a serious public health concern as it could result in outbreaks and increase the risk of morbidities and mortalities. Sociodemographic factors such as gender, occupation, age, poverty, and travel history have been reported to influence susceptibility and vulnerability to vector-borne illnesses [6], [7], [8].

Arboviral infections pose significant public health challenges globally, particularly in tropical and subtropical regions with favorable mosquito breeding conditions [9]. This geographical spread can be a result of changes in climate and human behavior, leading to greater exposure to the vectors [10]. Estimates show that Dengue virus (DengV) accounts for 100-400 million cases annually and Chikungunya virus (ChikV) results in an estimated 320,000 infections in 2023 [11], [12]. Zika virus (ZikV) which is endemic in the southern American region became a public health threat with a sporadic increase in the number of cases during the 2015-2016 outbreak and a decline in infections in 2017 [13]. Similarly, Yellow fever virus (YFV) is endemic in parts of Africa and South America and accounts for about 84,000-170,000 severe cases and 29,000-60,000 deaths annually [14]. Yellow fever has remained a public health problem in Nigeria and has been identified as an epidemic-prone disease [15]. Although most patients are asymptomatic, approximately 15-25% of infected symptomatic persons develop severe disease with case fatality rate (CFR) ranging from 3– 60% in previous epidemics [16]. However, the true incidence of DenV and ChikV infections in Nigeria is unknown.

Arboviruses are rarely ever investigated routinely among febrile cases in resource-limited regions. In Nigeria, arboviral infections are usually the least suspected febrile illnesses. They are often suspected when patients fail to respond to malaria treatment and other commonly suspected illnesses, resulting in delay in diagnosis and increased risk of morbidity and mortality [2], [17]. Thus, difficulties in differentiating arboviral infections from other febrile illnesses with similar clinical presentations, coupled with limited availability of diagnostics, are major challenges affecting the identification and treatment of arboviral infections in resource-limited regions. There is a

need to understand the true prevalence of common arboviral infections and possible co-infections among febrile patients in Nigeria. Therefore, this study investigated the prevalence and risk factors associated with malaria and selected arboviral infections in Nigeria.

2. Methodology

2.1. Study Design and Location

This cross-sectional study was conducted between October 2022 and September 2023 in the Federal Capital Territory (FCT), Lagos and Ogun states.

2.2. Sampling and Sample Size

Federal Capital Territory and the States were selected based on their epidemiological importance. In each state, a minimum of a secondary health facility was selected for the study. In Ogun state, State Hospital Ota, Federal Medical Centre Abeokuta, and Ijebu-Ife General Hospital were selected. Lagos State University Teaching Hospital, General Hospital Orile-Agege, and Randle General Hospital were selected in Lagos State. Bwari, Kubwa, Nayanya, and Asokoro General Hospitals were selected in the FCT. The sample size was calculated based on a 95% confidence level and a 5% margin of error. A total of 1020 blood samples were collected for the study.

2.3. Eligibility Criteria

Consenting participants, aged 5 years and above, presenting with fever at the time of visit to the hospital or symptoms of fever (body pains, headache, vomiting, and other symptoms suggestive of malaria and or typhoid fever) in the last 5 to 10 days before visiting the hospital were selected. Potential participants less than 5 years of age, not having fever, on treatment for malaria, non-consenting, with good health status, or with an existing chronic health condition or disease were excluded from the study.

2.4. Sample Collection

All sample analyses were conducted at the Institute of Human Virology Nigeria (IHVN), Abuja, and Inqaba Biotec Laboratory, Ibadan, Nigeria. About 5ml of venous whole blood sample was collected from each patient via vein puncture from the peripheral arm at the selected sample collection points in selected hospitals within the study areas [18]. The blood samples were processed into serum, aliquoted, and stored at -20°C before shipment. For malaria microscopy, blood smears were made on microscopic slides for thick and thin blood films, and dry blood spots were collected on 3MM Whatman filter paper for Polymerase Chain Reaction (PCR) assay. Blood

samples collected in plain sample bottles were allowed to stand for one hour to obtain serum. The serum was aliquoted into Eppendorf tubes and immediately transferred into the freezer where it was stored at -20°C until laboratory analysis.

Diagnosis of Malaria: Malaria was diagnosed using RDT (SD-Bioline™ by Standard Diagnostic Inc., Korea), microscopy, and PCR. Capillary blood from a finger prick was collected after cleaning with 70% alcohol. A thick blood smear was prepared on microscope slides for microscopy. The dried blood smears were stained with 10% Giemsa and placed in an incubator to dry. Two level 1 expert malaria microscopists independently conducted the microscopy test. Diagnoses were performed assuming a leukocyte count of $8,000/\mu\text{L}$. Counting the number of asexual parasites against about 200 leukocytes, we estimated the number of parasites [19].

PCR diagnosis was performed to detect malaria parasites. Blood spot was prepared on a filter paper (Whatman™ 3 MM) for Nested PCR, and dried in an area free of contamination and from the sun. This sample was subsequently stored in a zip-lock bag with silica gel to prevent the contamination and degradation of DNA. At the end of the study, dried blood spots on the filter were processed at the Inqaba Biotec laboratory, Ibadan, Nigeria, and DNA Labs Ltd, Abuja, Nigeria for DNA isolation and PCR amplification. The DNA in the blood spotted filter papers was extracted using Qiagen QIAmp DNA Blood Mini Kit and extracted DNA was stored at -20°C [20]. Primers used were those for nested PCR of 18S ribosomal RNA (rRNA) gene in malaria parasites which are rPLU5 and rPLU6 of *P. falciparum* species.

Plasmodium genus-specific amplification reaction was followed by a Nested PCR amplification reaction. The condition for the first amplification thermocycling was initial denaturation (94°C for 5 minutes), followed by 25 cycles of denaturation (94°C for 1 minute), annealing (58°C for 2 minutes), and extension (72°C for 2 minutes). For the nested PCR, the thermal conditions were similar except for 30 cycles of denaturation (94°C for 1 minute). The final extension was 5 min at 72°C for both primary and nested reactions and negative and positive controls were included for each PCR. After staining with Sybr™ Green, gel electrophoresis was conducted for the PCR products using 1.5% Agarose gel alongside a 100 bp DNA ladder (New England Biolabs UK) [21]. The detection of *Plasmodium falciparum* was confirmed with species-specific amplicon base pair sizes.

Diagnosis of Arboviruses: Viral RNA was extracted from the serum samples using the AVL buffer extraction method [22]. The extracted RNA was screened for DenV, ChikV, WNV, and ZikV using the Novaplex™ Tropical Fever Virus Assay by Seegene following the manufacturer's instructions. The detection was conducted on CFX96™ Real-time PCR detection System (Bio-Rad) equipment and analyzed using the Seegene viewer program. Results were interpreted as positive if internal control and

the sample were positive (at C_t value is ≤ 45), while negative if the sample was negative and internal control was positive (at C_t value is ≤ 45). The result was invalid and repeated if the internal control was negative but the sample was positive or negative.

A singleplex PCR was carried out to detect YFV. The extracted RNAs from samples were screened for the presence of YFV using the RealStar® YFV real-time PCR (RT-PCR) kit 1.0 (Altona Diagnostics). The kit is an in-vitro diagnostic test, based on RT-PCR technology, for the qualitative detection of YFV-specific RNA. The guidelines used were those provided by the manufacturer. RT-PCR was done on CFX96™ PCR Detection System (Bio-Rad) equipment and analyzed using fluorescence detectors (dyes). Results were interpreted as positive if the internal control had fluorescence and the sample had fluorescence, while negative if the sample had fluorescence and the internal control did not. The result was invalid and repeated if the internal control did not have fluorescence.

A conventional PCR was carried out for DenV, ChikV, YFV, and WNV. Primers used were as those described in previous studies [23], [24], [25]. The genes targeted by these primers were the NS1 gene within the DVT2 flavivirus polyprotein of DenV type II, the E1 gene within the CV alphavirus polyprotein of ChikV, the NS2 gene within the YFV flavivirus polyprotein of YFV and NS2 gene within the WNV flavivirus polyprotein of WNV. The primer sequences for the conventional PCR to amplify DenV, ChikV, YFV, and WNV are presented in Table 1. A step-by-step working protocol for the PCR reaction was designed and reagents and primers purchased from manufacturers were reconstituted according to the protocol specifications of concentrations and volumes. The amplified products were visualized in 2% agarose gels stained with ethidium bromide [26]. The gel was viewed under ultraviolet transillumination. A media device was used to capture the image of the test sample and the deoxyribonucleic acid (DNA) ladder band on the agarose agar gel [21].

2.5. Statistical Analysis

Data was transcribed into Microsoft Excel 365 for data cleaning and coding while analyses were performed using Stata (version 17). Descriptive statistics were presented in frequencies, percentages, tables, and charts. Chi-squared analysis was conducted to assess the association between independent variables and study outcomes, while the Fisher exact test was applied when assumptions for Chi-square were not met. All statistical tests were carried out at a 5% level of significance.

2.6. Ethical Approval

Ethical approval for the study was obtained from the Covenant University Health Research Ethics Committee (CHREC/170/2022), the ethical review committee of

Lagos University Teaching Hospital (LASUTH) (LREC/06/10/1815), State Ministry of Health, Ogun State (HPRS/381/449), and the FCT Hospital Management Board (FHREC/2022/01/174/05-09-22). The consent of potential participants and parents of children below the age of consent was sought and obtained following research ethics guidelines using consent forms. Data were deidentified to protect the confidentiality of study participants.

3.1. Demographic Profile of Participants

A total of 1020 febrile patients participated in this study of which 627 (61%) were females and 393 (39%) were males. The ages of participants ranged between 5 and 83 years, and the mean age was 37. Business/trading 393 (39%), students 214 (21%), and civil servants 187 (18%) were the most popular occupations among study participants, while 5 (0.5%) were farmers (**Table 1**).

3. Result

Table 1. Sociodemographic and health characteristics of participants

Variable	Male		Female		Total	
	n	%	n	%	N	%
State						
FCT	135	34.6	255	65.4	390	38.2
Lagos	172	44.1	218	55.9	390	38.2
Ogun	86	35.8	154	64.2	240	23.5
Occupation						
Student	95	45.2	115	54.8	210	20.6
Clerical/paid job	143	45.3	173	54.7	316	31
Business/trading	104	29.7	246	70.3	350	34.3
Farming	2	40	3	60	5	0.5
Housewife	0	0	10	100	10	1
Unemployed	49	38.3	79	61.7	128	12.5
Season						
Rainy	284	72.3	466	74.3	750	73.5
Dry	109	27.7	161	25.7	270	26.5
Travel history (less than 3 weeks before illness)						
Yes	55	14	70	11.2	125	12.3
No	338	86	557	88.8	895	87.7
Symptom						
Fever	362	92.1	570	90.9	932	91.4
Cold	85	21.6	148	23.6	233	22.8
Convulsion	6	1.5	4	0.6	10	1
Headache	306	77.9	461	73.5	767	75.2
Stomach pain	53	13.5	100	15.9	153	15
Rash	1	0.3	5	0.8	6	0.6

Note: n=number; FCT=Federal Capital Territory, %=percent

3.2. Prevalence of Malaria and Arboviral Infection

A total of 12% (119) tested positive for malaria, 3.3% (34) for DenV, 5.7% (58) for ChikV, 23.3% (238) for ZikV, 5.8% (59) for WNV and 2% (20) for YFV (**Figure 1**). ZikV had the highest prevalence in Lagos (29.0%) and Ogun states (25.0%), while YFV was the lowest (<1.0%). However, malaria (17.2%) was most prevalent in the FCT followed by ZikV (16.9%). The prevalence of malaria was similar in FCT (17.2%) and Ogun state (17.5%) and lower in Lagos State (2.6%).

3.3. Prevalence of Malaria and Arboviral Infection among Study Participants by Age Group

Across all age groups, ZikV was more prevalent (18.3-27.1%) followed by malaria (11.6-15.8%) among participants aged <15 years and 15-24 years old compared to ChikV among participants \geq 50 years old (7.0%). On the other hand, YFV was lowest among participants aged 15-24 and 25-49 years (0.9% each), and DenV was lowest among <15 years old. When prevalence was stratified by gender, ZikV was more predominant among males (24.2%) and females (23.1%) followed by malaria in males (13.2%) and females (10.7%), while YFV was least prevalent among males and females (2.0%) followed by DenV (3.3%) (**Figure 2**).

3.4. Prevalence of Malaria and Arboviral Infection by Season

The prevalence of malaria was higher during the rainy season (17.0%) compared to the dry season (10.0%). During the dry season, the prevalence of DenV was higher (4.0%) compared to the rainy season (1.0%). Similarly, the prevalence of ChikV (6.0%) was higher during the dry season (4.0%). ZikV prevalence was higher during the dry season (26.0%) compared to the rainy season (18.0%) and higher prevalence was found for WNV (6.0%) during the dry season compared to the rainy season (4.0%). Double the prevalence of YFV was found during the dry season (2.0%) compared to the rainy season. However, the prevalence of malaria was higher during the rainy season (19.0%) compared to the dry season (10.0%) (**Figure 3**).

3.5. Prevalence of Single Infection, Malaria-Arboviral Co-infection and Arboviral Co-infection

About 36.8% (375) of participants tested positive for at least one of the mosquito-borne infections. Malaria infection only accounted for 10% (97) of all fever cases while the remaining 27.0% (278) were caused by an arbovirus infection, malaria-arbovirus co-infection, or

arbovirus co-infection (**Figure 4**). Prevalence of CZ coinfection was 4.6%, ZW coinfection was 3.3%, CW coinfection was 3.1%, CZW coinfection was 2.7%, DC coinfection was 2.5%, DZ coinfection was 2.1%, DCZ coinfection was 2.1%, MZ coinfection was 1.9%, DW coinfection was 1.6%, DCW coinfection was 1.6%, DZW coinfection was 1.5%, DCZW coinfection was 1.3%, MC coinfection was 0.5%, MW coinfection was 0.5%, MCZ coinfection was 0.4%, MY coinfection was 0.4%, MD coinfection was 0.3%, MDC coinfection was 0.3%, MDZ coinfection was 0.3%, MDW coinfection was 0.3%, MCW coinfection was 0.3%, MZW coinfection was 0.3%, MDCZ coinfection was 0.3%, MDCW coinfection was 0.3%, MDZW coinfection was 0.3%, MCZW coinfection was 0.3%, MDCZW coinfection was 0.3%, ZY coinfection was 0.3%, DCZY coinfection was 0.1%, DY coinfection was 0.1%, DCY coinfection was 0.1%, DZY coinfection was 0.1%, CY infection 0.1%, CZY coinfection was 0.1% (**Figure 4**). (Key: M – Malaria, D – Dengue, C- Chikungunya, Y- yellow fever, Z- Zika, W- West Nile)

While 53.8% of the participants had no infection, the prevalence of single infection was 23.2% (278), and double infections 4.6% (55), three infections 2.6% (27), four infections 1.2% (12) while five infections accounted for 0.3% (3) of the study participants. There was no case of six infections among study participants. (**Figure 5**).

3.6. Risk Factors of Malaria and Arboviral Infection

There was a statistically significant association between age group and the prevalence of YFV ($X^2=5.69$, P -value=0.017) while age group was not significantly associated with the other arboviral infections ($P>0.05$) (**supplementary table 1**). Similarly, travel history was significantly associated with the prevalence of malaria ($X^2=6.52$, P -value=0.001) and DenV ($X^2=4.91$, P -value=0.027) while the association between travel history and other arboviral infections was insignificant (P -value>0.05) (**Supplementary table 2**). Seasonality was significantly associated with malaria ($X^2=10.28$, P -value=0.001), DenV ($X^2=7.67$, P -value=0.006), and ZikV ($X^2=6.54$, P -value=0.011) while this was not significant for other arboviral infections (**Supplementary table 3**). State of residence was significantly associated with all arboviral infections and malaria ($X^2=50.78$), ChikV ($X^2=11.69$), ZikV ($X^2=16.22$), WNV ($X^2=18.52$) and YFV ($X^2=19.15$) (P -value<0.003) (**Supplementary table 4**). Lastly, occupation was associated with malaria ($X^2=13.27$, P -value=0.021), ChikV ($X^2=11.78$, P -value=0.038), YFV ($X^2=21.03$, P -value=0.001), ZikV ($X^2=17.31$, P -value=0.004) (**Supplementary table 5**).

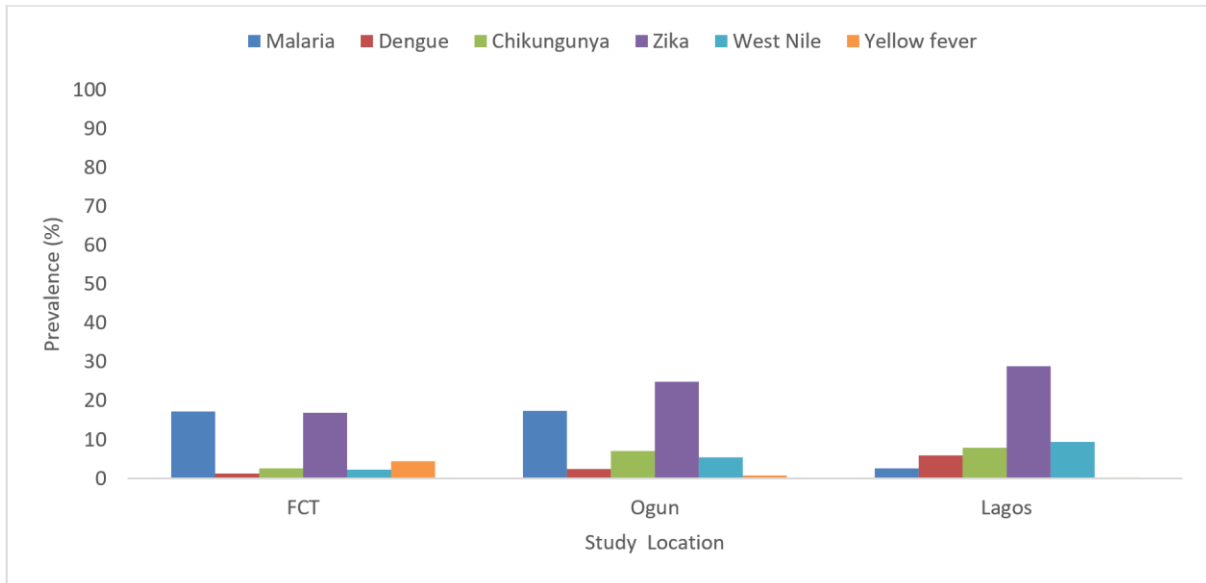


Figure 1. Prevalence of malaria and arbovirus infection by State

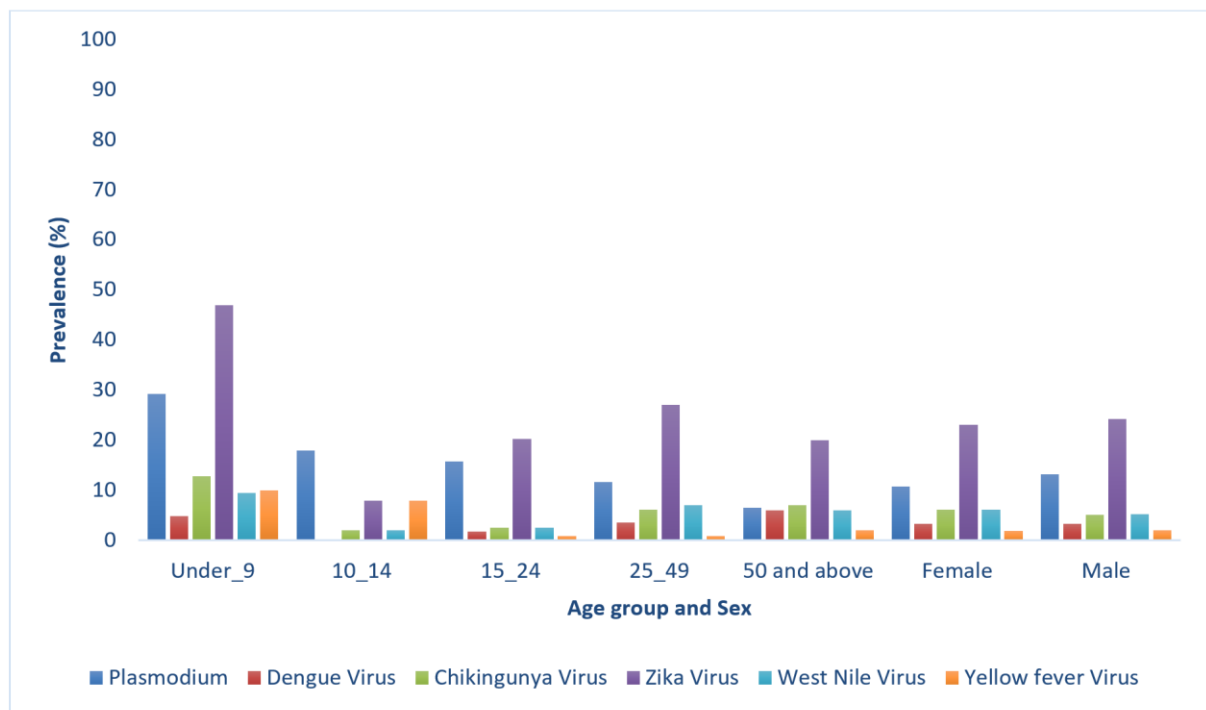


Figure 2. Prevalence of malaria and arbovirus infection by age and sex (percentage)

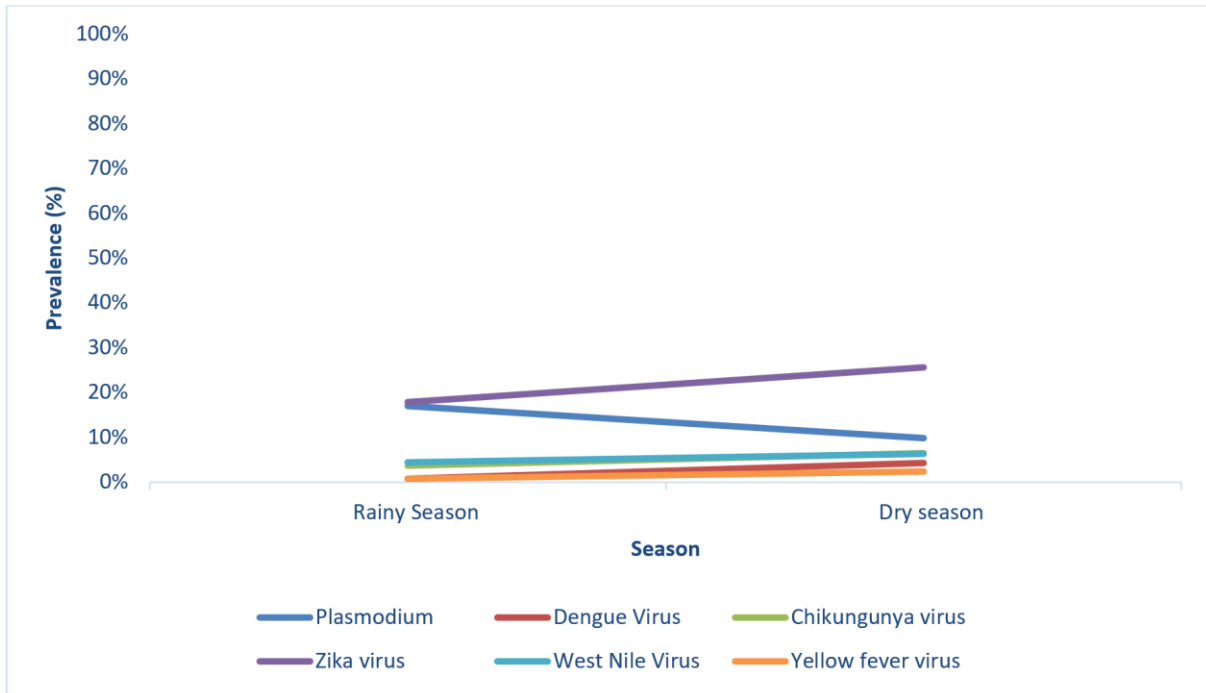


Figure 3. Prevalence of malaria and arbovirus infection by season (percentage)

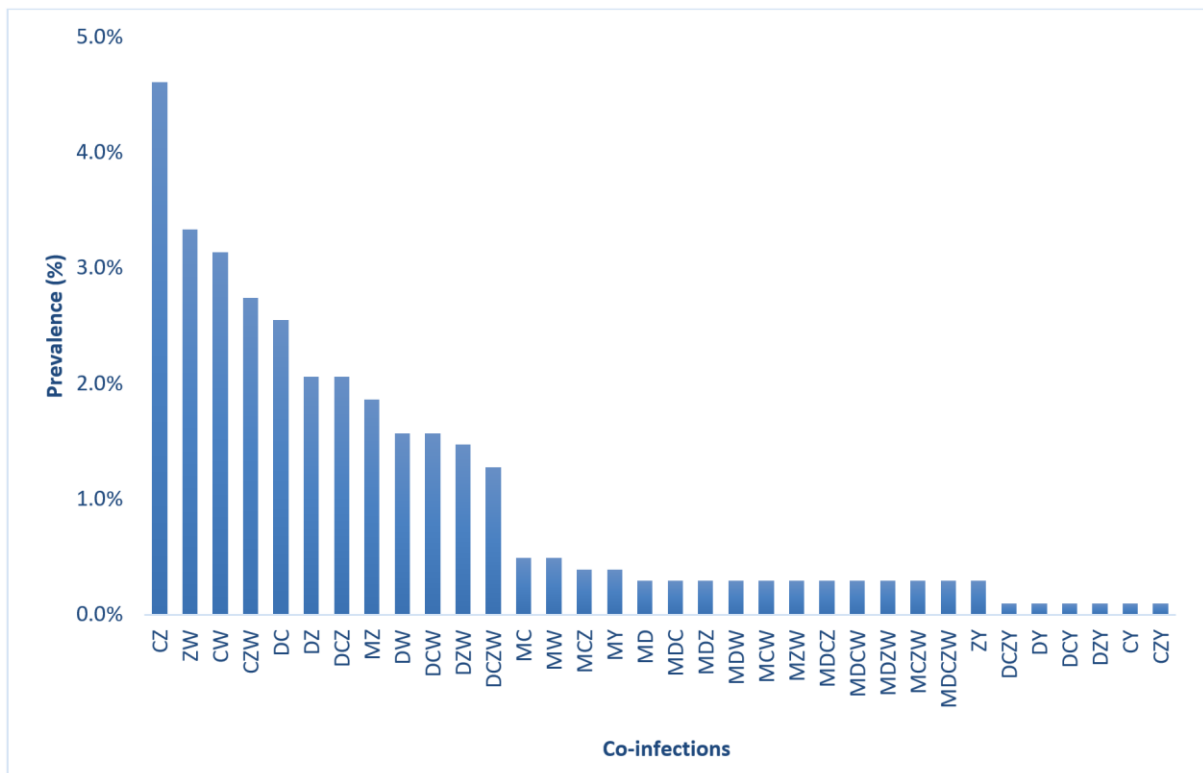


Figure 4. Prevalence of malaria-arboviral co-infection and arboviral co-infection (percentage)

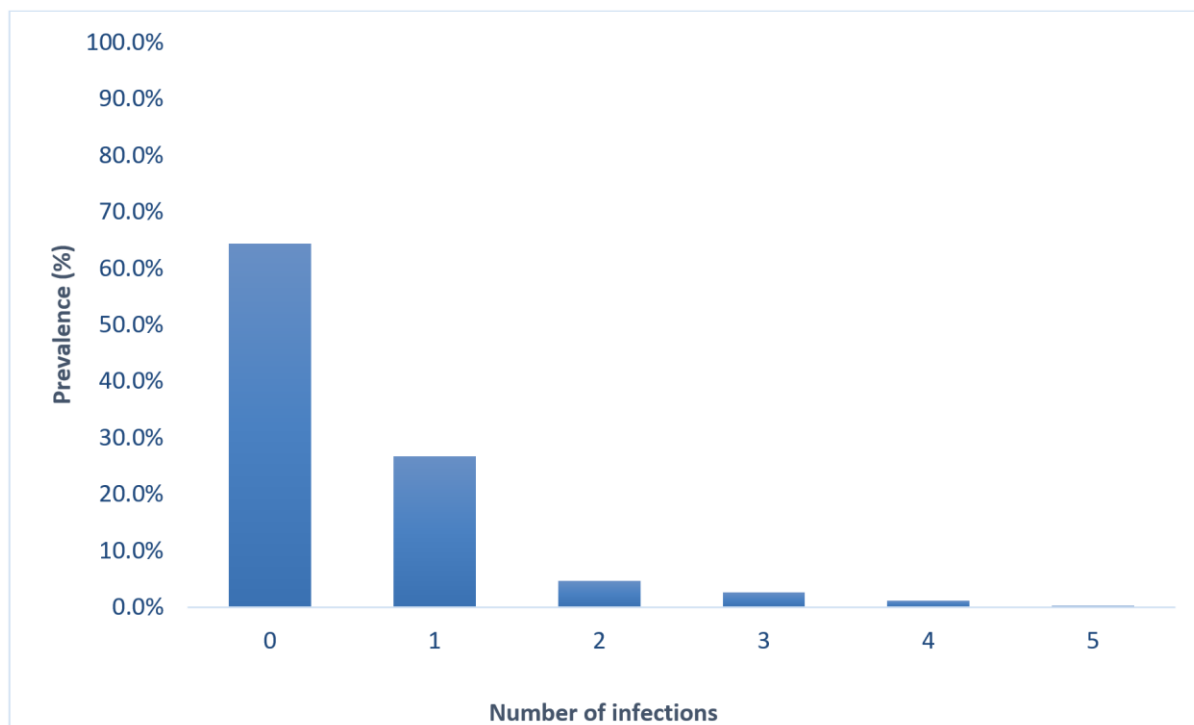


Figure 5. Distribution of the number of single infections and co-infections by number of cases (percentage)

4. Discussion

This study investigated the prevalence and risk factors associated with Malaria, arboviral infections, and malaria-arboviral co-infection in FCT, Lagos, and Ogun States, Nigeria. The prevalence of malaria among study participants was 12%. While this was similar to findings from other studies, the prevalence of malaria in this study was much lower than the 23% prevalence of malaria reported [27], [28], [29]. The prevalence of malaria in this study reported 17% from FCT and Ogun State and only 3% in Lagos State compared to a study conducted in the FCT which found 54% of malaria cases among residents of Abuja [30].

Nigeria is faced with a huge burden of mosquito-borne diseases which can be attributed to its tropical climate, providing a breeding environment for mosquitoes. As a result, malaria has been identified to be the most predominant disease affecting the Nigerian population [31]. However, our study found that the prevalence ZikV was higher than malaria, which contrasts with a recent study conducted on a similar population in Nigeria which found a malaria prevalence of 40% compared to 6.2% for ZikV [32]. Similarly, another study conducted in south-eastern Nigeria reported a higher malaria prevalence (55%) compared to ZikV (15%) [33]. Although our study does not provide statistical evidence for this variation, we suggest that the expanded malaria control programs within these regions, population immunity, increased awareness, and practices may have contributed to the lower prevalence of malaria compared to ZikV. Also, only positive cases of

malaria by RDT were further assessed using microscopy and PCR. As a result, the lower sensitivity of mRDT compared to other malaria diagnostics methods may affect the diagnosis of malaria cases. This finding may also be suggestive of an undetected increase in ZikV transmission in Nigeria in recent times compared to previous studies [33], [34]. However, a ZikV prevalence of 15% has previously been reported in Adamawa and Borno states [35].

Apart from ZikV, the prevalence of other arboviral infections in our study was <6%. This compares favorably with a prevalence of less than 7% reported in previous studies [36], [37], [38], [39]. However, a study conducted in Thailand revealed a 21% prevalence of ZikV [40]. Also, the South American region has been seen to have a higher prevalence of arboviral infections, with Brazil accounting for the highest burden. [41]. While arboviral infections are less prevalent in Nigeria, it is important to note that the country's ecological conditions increase the risk of these disease outbreaks due to an environment that favors the proliferation of mosquitoes, the primary vectors for *Plasmodium species* and arboviruses. The tropical climate characterized by high temperatures and high humidity, provides an ideal breeding ground for these vectors, thereby increasing the risk of malaria arbovirus transmissions.

In our study, the prevalence of malaria was predominant among participants under the age of 15 years and 15-24 years old while DenV and WNV infection was higher among older participants. This agrees with similar findings from previous studies that found higher risk of malaria among the younger age groups [30], [42]. Adults have

typically been exposed to multiple malaria and arboviral infections, leading to the development of partial immunity [43], [44]. Also, adults are knowledgeable about malaria prevention and will likely engage in preventive measures [45]. Our study found that except for ChikV and WNV, the prevalence of arboviral infections was higher among males compared to females. This finding agrees with previous studies that have reported higher arboviral infections in males compared to females which may be affected by environmental and behavioral factors [38], [46]. Males are more likely to be found in areas that breed mosquitoes compared to females thereby exposing the gender to the risk of exposure to the vectors. However, another study revealed that females were more affected by malaria and arboviral co-infection than their male counterparts [3]. Notably from this study, more females assessed care at the healthcare facility and were more likely to be recruited into the study which may have influenced the prevalence. The rate of malaria infections was higher during the rainy season and lower during the dry season while for DenV, ChikV, ZikV, WNV, and YFV infections, prevalence was higher during the dry season. Generally, Anopheles mosquitoes thrive in stagnant water, which is abundant during the rainy season. Thus, increased rainfall provides breeding sites for mosquitoes, facilitating their reproduction and the transmission of *Plasmodium* parasites. But mosquitoes transmitting arboviral infections such as *Aedes aegypti* and *Aedes albopictus* prefer breeding in clean water, which may be more prevalent during the dry season.

Although more than half of the population had no infection, our study found that the proportion of participants with only one infection was higher than those with multiple, corroborating the finding from a similar study [2]. Other studies have also shown similar prevalence of malaria and arboviral co-infection [47], [48]. According to the World Health Organization (WHO), co-infection of malaria and arboviruses is entomologically valid as vectors transmitting these etiologies have tested positive for multiple viruses and *Plasmodium* simultaneously, suggesting that humans may be infected with two or more viruses simultaneously from a single mosquito bite [49].

This study revealed that State of residence was a statistically significant risk factor for all selected vector-borne infections. This is similar to a study that found that locations with mosquito vector breeding grounds had a higher prevalence of arboviruses [50]. Also, travel history was significantly associated with malaria and DenV infections which was corroborated in a study that reported travel-related cases of WNV [51]. According to another study, travelers, tourists, and healthcare professionals were more likely to transport diseases into a new location than migrants or refugees [52]. It has been established that infectious disease spread can be facilitated by travels

within and out of endemic regions [53]. Therefore, people who travel to endemic countries are at higher risk of infection.

This study found significant seasonal variation for malaria, DenV, and ZikV infections which agrees with a study that revealed that varying climates, ecosystems, and vector control measures impact the transmission dynamics of arboviruses [54]. *Aedes aegypti* breeds mostly in natural and artificial habitats where there is a collection of water such as rainwater which aids the reproduction of immature *Aedes* species that spread arboviruses. This may explain how the variation in the weather conditions could influence the breeding of vectors and increase the risk of infections. However, even in the absence of rainfall, other forms of water collection within the environment serve as alternative breeding sites for both *Anopheles* and *Aedes* species mosquitoes. Our study also found that occupation was significantly associated with malaria, ChikV, YFV, and ZikV infections. This agrees with a study conducted in 2021 which identified higher cases of arboviral infections among civil servants compared to self-employed [55].

This study is not without limitations. This study was only conducted in three Nigerian states and the result may not be generalized. Also, the study only assessed the association between selected socio-demographic factors and the prevalence of malaria and arboviral infections, and findings from this study cannot infer causality. However, this study provides evidence of arboviral infections, and co-infection in FCT, Lagos, and Ogun States. These findings may inform the development of appropriate mitigation strategies.

5. Conclusions

Our findings reveal that travel history, seasonality, and occupation were associated with malaria and arboviral infections. Also, our study found that ZikV was more prevalent than malaria and other arboviral infections. This finding shows a potential shift in the epidemiologic landscape of vector-borne disease. However, further studies to corroborate this finding and determine the extent to which ZikV is transmitted across the population are important. There is also a need for interventions to improve the knowledge and index of suspicion for arboviral infections across health facilities. The existing surveillance and early warning systems for arboviral infection must be strengthened for the timely detection and control of infectious disease outbreaks. Because these diseases are caused by similar vectors, an integrated approach targeted at the prevention of human and mosquito interaction could be effective in mitigating the risk of the diseases among Nigerian inhabitants.

Supplementary Materials

Supplementary Table 1. Association between Age group and having malaria and arbovirus infections

Diseases	Age group	Prevalence	Confidence interval	Chi square	P-value
Malaria	0-9years	15.5	8.9 – 24.2	1.499	0.221
	10+ years	11.3	9.7 – 13.8		
Dengue	0-9years	2.1	0.2 – 7.2	0.538	0.463
	10+ years	3.5	2.3 – 4.6		
Chikungunya	0-9years	6.2	2.3 – 12.9	0.049	0.823
	10+ years	5.6	4.3 – 7.3		
Zika	0-9years	22.7	14.7 – 32.3	0.034	0.854
	10+ years	23.5	20.9 – 26.2		
West Nile	0-9years	4.1	1.1 – 10.2	0.542	0.461
	10+ years	6	4.4 – 7.4		
Yellow fever	0-9years	5.2	1.7 – 11.6	5.688	0.017*
	10+ years	1.6	1.2 – 3.0		

Supplementary Table 2. Association between Travel history and malaria and arbovirus infection

Diseases	Travel history	Prevalence	Confidence interval	Chi-square	P-value
Malaria	Yes	4.8	0.2 - 10.2	6.518	0.001
	No	12.6	10.5 - 15.0		
Dengue	Yes	0	0.0 - 2.9	4.912	0.027
	No	3.8	2.6 - 5.3		
Chikungunya	Yes	2.4	0.5 - 6.9	2.869	0.09
	No	6.1	4.7 - 7.9		
Zika	Yes	21.6	14.7 - 29.8	0.266	0.606
	No	23.7	20.9 - 26.6		
West Nile	Yes	2.4	0.5 - 6.9	2.994	0.084
	No	6.3	4.8 - 8.0		
Yellow fever	Yes	2.4	0.5 - 6.9	0.143	0.705
	No	1.9	1.1 - 3.0		

Supplementary Table 3. Association between Season (dry/rainy) and malaria and arbovirus infection

Diseases	Season	Prevalence	Confidence interval	Chi-square	P-value
Malaria	Dry	9.7	7.7 - 12.1	10.276	0.001
	Rainy	17	12.8 - 22.1		
Dengue	Dry	4.3	2.9 - 6.0	7.66	0.006
	Rainy	0.7	0.1 - 2.7		
Chikungunya	Dry	6.4	4.8 - 8.4	2.691	0.101
	Rainy	3.7	1.8 - 6.7		
Zika	Dry	25.5	22.4 - 28.7	6.542	0.011
	Rainy	20.1	13.4 - 22.9		
West Nile	Dry	6.3	4.6 - 8.2	1.21	0.271
	Rainy	4.4	2.3 - 7.6		
Yellow fever	Dry	2.4	1.4 - 3.8	2.843	0.092
	Rainy	0.7	0.1 - 2.7		

Supplementary Table 4. Association between State of Residence and malaria and arbovirus infection

Diseases	State	Prevalence	Confidence interval	Chi-square	P-value
Malaria	FCT	17.2	13.6 - 21.3	50.78	<0.001
	Lagos	2.6	1.20 - 4.70		
	Ogun	17.5	12.9 - 22.9		
Dengue	FCT	1.3	0.4 - 3.0	13.568	0.001
	Lagos	5.9	3.8 - 8.7		
	Ogun	2.5	0.9 - 5.4		
Chikungunya	FCT	2.6	1.2 - 4.7	11.685	0.003
	Lagos	7.9	5.5 - 11.1		
	Ogun	7.1	4.2 - 11.1		
Zika	FCT	16.9	13.3 - 21.0	16.216	<0.001
	Lagos	29	24.5 - 33.8		
	Ogun	25	19.7 - 31.0		
West Nile	FCT	2.3	1.1 - 4.3	18.521	<0.001
	Lagos	9.5	6.8 - 12.8		
	Ogun	5.4	2.9 - 9.1		
Yellow fever	FCT	4.4	2.6 - 6.9	19.149	<0.001
	Lagos	0.3	0.0 - 1.4		
	Ogun	0.8	0.1 - 3.1		

Supplementary Table 5. Association between Occupation and malaria and arbovirus infection

Diseases	Season	Prevalence	Confidence interval	Chi-square	P-value
Malaria				13.27	0.021*
	Student	16.7	11.9-22.4		
	Clerical/paid job	9.8	6.8-13.6		
	Business/trading	8.9	6.1-12.3		
	Farming	20	0.5-71.6		
	Housewife	0	0.0-30.8		
	Unemployed	16.4	10.5-24.0		
Chikungunya				11.78	0.038*
	Student	4.3	2.0-8.0		
	Clerical/paid job	4.4	2.4-7.3		
	Business/trading	8.3	5.6-11.7		
	Farming	0	0.0-52.2		
	Housewife	20	2.5-55.6		
	Unemployed	3.1	0.9-7.8		
Yellow fever				21.03	0.001*
	Student	0.5	0.0-2.6		
	Clerical/paid job	1.9	0.7-4.1		
	Business/trading	1.1	0.3-2.9		
	Farming	0	0.0-52.2		
	Housewife	0	0.0-30.8		
	Unemployed	7	3.3-12.9		
Dengue				5.159	0.397
	Student	2.4	0.8-5.5		
	Clerical/paid job	2.2	0.9-4.5		
	Business/trading	4.6	2.6-11.7		
	Farming	0	0.0-52.2		
	Housewife	10	0.3-44.5		
	Unemployed	3.9	1.3-8.9		
Zika				17.31	0.004*
	Student	20	14.8-26.1		
	Clerical/paid job	26.3	21.5-31.5		
	Business/trading	27.4	22.8-32.4		
	Farming	20	5.0-71.6		
	Housewife	30	6.7-65.2		
	Unemployed	10.9	6.1-17.7		
West Nile				10.1	0.072
	Student	4.8	2.3-8.6		
	Clerical/paid job	4.4	2.4-7.3		
	Business/trading	8.9	6.1-12.3		
	Farming	0	0.0-52.2		
	Housewife	0	0.0-30.8		
	Unemployed	3.1	0.9-7.8		

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Author Contributions

AFI, OOA, KMO, and GIO conceptualized the study and devised the methodology including data collection. AFI and TM carried out the sample analysis and laboratory work. SOO, RIO, ODO, and MB supported the sample analysis and the laboratory work. AFI and TAA curated the data and performed the formal analysis. AFI wrote the original draft of the manuscript. ODO, and MB validated the study. OOA, KMO, and GIO supervised the study. All authors reviewed and edited the paper. All the authors have read and approved the paper.

Competing Interest

The authors declare no competing interest in the conduct of this study.

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