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RESEARCH

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The interplay of socio-demographic factors and disease prevalence: insights into malaria, Hepatitis B, and Hepatitis C in Lafia, Nasarawa State, Nigeria

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Abstract

Background Infectious diseases, including malaria, Hepatitis B surface antigen (HBsAg), and Hepatitis C virus (HCV), remain significant public health concerns in developing regions like Lafia, Nasarawa State, Nigeria. Socio-demographic factors, such as gender, age, income level, and access to healthcare resources, have been shown to influence the prevalence and outcomes of these diseases. Despite their importance, there is limited research exploring the interrelationship between these infections and socio-demographic factors within this region. The study aims to investigate the prevalence of malaria, HBsAg, and HCV among patients in Lafia, Nigeria, and to examine the relationship between these infections and socio-demographic factors. Specifically, it seeks to identify correlations between demographic variables, clinical manifestations, and health behaviors, such as mosquito net usage and vaccination status.

Method A cross-sectional design was employed, involving 264 patients from Lafia, Nasarawa State, Nigeria. Data were collected using structured questionnaires which were pretested in a previous study to gather demographic information, vaccination status, and clinical symptoms. Laboratory assessments confirmed the presence of malaria, HBsAg, and HCV. Statistical analysis, including correlations between socio-demographic factors and disease prevalence were analyzed, and used to identify associations between socio-demographic factors, clinical manifestations, and disease prevalence.

Results Significant findings include a negative correlation between male sex and malaria infection (Pearson Correlation = -0.139, $p = 0.024$), a positive correlation between age and HCV prevalence (Pearson Correlation = 0.218, $p < 0.001$), and a negative correlation between the use of mosquito nets and malaria infection (Pearson Correlation = -0.231, $p < 0.001$). Additionally, HBsAg-positive individuals exhibited more pronounced clinical symptoms (Pearson

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Correlation = 0.173, *p* = 0.005), while higher income levels correlated with reduced mosquito net usage (Pearson Correlation = -0.144, *p* = 0.020). The study underscores the role of socio-demographic factors in shaping the prevalence of malaria, HBsAg, and HCV.

Conclusion This study highlights the interplay between socio-demographic factors and the prevalence of malaria, HBsAg, and HCV in Lafia, Nigeria. It underscores the importance of comprehensive public health interventions tailored to the specific needs of the population to reduce disease burden and improve health outcomes, including health education, to address socio-economic vulnerabilities and promote preventive measures such as mosquito net usage. Addressing these factors could mitigate the burden of infectious diseases in Lafia and similar regions.

Keywords Socio-demographic factors, Malaria, Hepatitis B surface antigen (HBsAg), Hepatitis C virus (HCV), Lafia, Nasarawa State

Introduction

Infectious diseases remain a major public health challenge in sub-Saharan Africa, with malaria, Hepatitis B, and Hepatitis C contributing significantly to the burden of morbidity and mortality [1–5]. Malaria, caused by *Plasmodium* parasites and transmitted through the bite of infected *Anopheles* mosquitoes, is endemic in Nigeria, accounting for a substantial proportion of global cases and deaths [6–9]. In 2020, Nigeria was responsible for 27% of global malaria cases and 31% of malaria deaths, with children under five and pregnant women being the most vulnerable groups [10–11]. Despite extensive malaria control efforts, including insecticide-treated nets (ITNs) and intermittent preventive therapy, the disease continues to exert a heavy toll on the country's health system, especially in rural and semi-urban areas like Lafia, Nasarawa State [12–13].

Hepatitis B virus (HBV) and Hepatitis C virus (HCV) are also major contributors to liver-related diseases in Nigeria [14–16]. HBV and HCV are bloodborne viruses that can lead to chronic liver disease, cirrhosis, and hepatocellular carcinoma (liver cancer) if left untreated [14–16]. Hepatitis B is highly endemic in Nigeria, with an estimated prevalence of 8.1% among adults, making it a significant public health issue [17–19]. HBV is commonly transmitted through perinatal transmission, unprotected sexual contact, and exposure to infected blood, including unsafe medical procedures and traditional practices like scarification [20–21]. Although vaccination against HBV is included in Nigeria's Expanded Programme on Immunization (EPI), coverage remains uneven, particularly in rural areas [6, 22–24].

Hepatitis C, while less prevalent than Hepatitis B, poses a serious health risk due to its chronic nature and the difficulty in diagnosing it in its early stages [25–26]. It is estimated that 80 million people worldwide suffer from chronic infections, and 110 million people have a history of HCV infection [25]. According to different studies, the moderate frequency in the sub-Saharan African region ranges from 1.5 to 3.5% [25]. The prevalence of HCV is 2.2% in Nigeria [25].

HCV transmission occurs primarily through blood-to-blood contact, with unsafe injections, unsterilized medical equipment, and sharing of needles being the leading causes in Nigeria [16]. The disease often progresses silently over decades, leading to liver damage that may only be detected at advanced stages [25]. With limited access to antiviral therapies and diagnostic facilities in many parts of Nigeria, HCV continues to pose a significant threat to the health of affected populations [26–28].

Lafia, the capital of Nasarawa State, is representative of many rural and semi-urban areas in Nigeria, where healthcare infrastructure is limited, and public health initiatives often face significant challenges. In such regions, the prevalence of infectious diseases is influenced by socio-demographic factors, healthcare accessibility, environmental conditions, and local practices. Understanding the specific epidemiology of malaria, HBV, and HCV in these settings is critical to formulating targeted interventions and improving disease control [29–30].

While there is a growing body of research on malaria and viral hepatitis in Nigeria, few studies have focused on the intersection of these diseases and how socio-demographic factors, such as age, gender, marital status, and behavioral practices, contribute to their prevalence in semi-urban areas like Lafia. Additionally, the influence of preventive measures, such as the use of ITNs for malaria prevention, and the gaps in vaccination for HBV, have not been comprehensively studied in this population.

This research addresses an important gap by focusing on the intersection of malaria, Hepatitis B, and Hepatitis C in Lafia, emphasizing how socio-demographic factors contribute to the prevalence of these infections. By exploring these relationships in the context of a rural and semi-urban setting like Lafia, this study provides unique insights that are not sufficiently covered in previous research, and aims to fill this gap by investigating the prevalence of malaria, Hepatitis B (HBsAg), and Hepatitis C (HCV) among individuals in Lafia, while exploring the demographic factors that may influence infection rates. By examining the relationship between disease prevalence and variables such as age, gender, marital status, and ITN usage, this study seeks to provide data that can inform more effective public health interventions in the region. The findings will contribute to the broader understanding of infectious disease epidemiology in rural Nigeria, with the ultimate goal of improving disease prevention and control strategies.

Methods

Study area

Nasarawa State is situated in the North-Central region of Nigeria, bordered by the Federal Capital Territory to the south and several states including Benue to the east and Plateau to the north. According to the 2006 census, Nasarawa State has a population of approximately 1,163,282, making it one of the less populous states in Nigeria [31]. The state is home to diverse ethnic groups, with the predominant groups being the Alago, Kanuri, and Gwandara peoples, alongside several other communities, including the Hausa, Eggon, and Tiv. The capital of Nasarawa State is Lafia, which serves as an administrative and commercial hub for the region [31].

Lafia is strategically located within the state, lying at longitude 8° 31' and 9° 0' East, and latitude 8° 21' and 8° 30' North (Fig. 1). This city has experienced significant growth in recent years, driven by its role as a center for trade and commerce. The urbanization of Lafia has attracted a mix of people from various backgrounds, contributing to its cultural diversity.

The climate of Nasarawa State, including Lafia, is classified as Aw according to the Köppen climate classification, characterized by tropical savanna conditions [31]. The region experiences two primary seasons: a wet season and a dry season. The wet season typically occurs from April to October, characterized by well-distributed rainfall and a monthly mean of about 145.23 mm, culminating in an annual average of approximately 1,161.04 mm. The peak rainfall occurs in July and August, contributing to the lush vegetation that defines the landscape during this period.

Conversely, the dry season spans from November to March, marked by significantly reduced rainfall. During this period, mean monthly relative humidity ranges from 20 to 35%, in stark contrast to the rainy season, where humidity can reach up to 75%. Mean daily temperatures in Lafia fluctuate between 20 °C in December and January and can rise to 39 °C in March, with an annual mean temperature hovering around 27 °C.

The combination of geographical, climatic, and cultural factors in Nasarawa State and Lafia plays a crucial role in shaping the health outcomes of the population. Challenges such as limited healthcare infrastructure, variations in health-seeking behaviors, and socio-economic disparities have a profound impact on the management

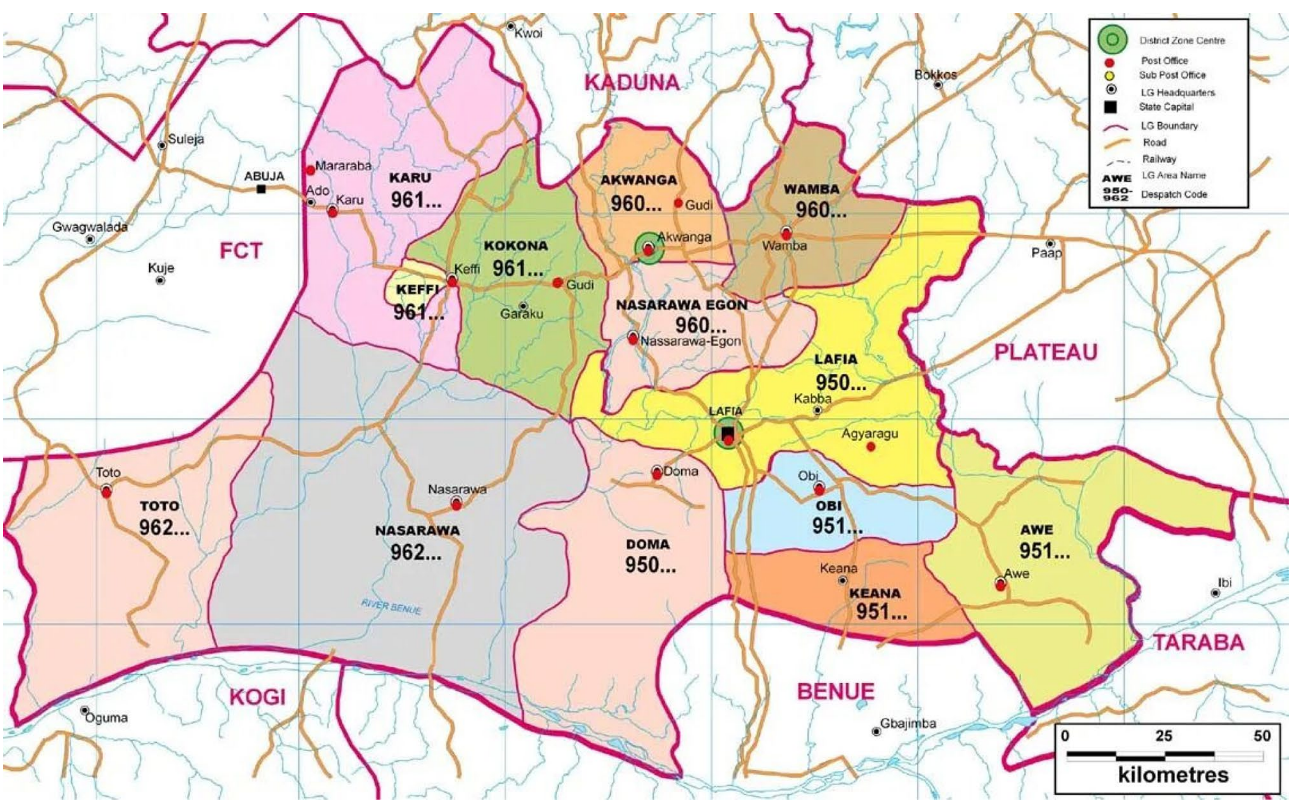

Fig. 1 Image showing the study location (Lafia, Nasarawa State) used for the study in yellow colour

of infectious diseases, including viral hepatitis. As Lafia continues to grow as a focal point for economic activities, understanding its demographic and environmental context is essential for implementing effective public health strategies tailored to the unique needs of its residents.

Research design

This study is a six-month community-based prospective longitudinal and cross-sectional survey conducted in Lafia, Nasarawa State, Nigeria. Data collection was concentrated in the Lafia East section of the Lafia Local Government Area, utilizing the Otunsha Foundation as a key partner in the research initiative. The choice of a community-based approach allowed for an in-depth understanding of the health dynamics within the population. The prospective longitudinal aspect of the study enabled researchers to follow the same individuals over time, allowing for the observation of disease progression, patterns of health-seeking behavior, and responses to interventions. Simultaneously, the cross-sectional component provided a snapshot of the prevalence of malaria and viral hepatitis at a specific point in time, facilitating a comprehensive analysis of the health status of the community.

Data collection was conducted using structured questionnaires and clinical assessments, which were administered by trained field researchers. These tools were designed to capture a wide range of information, including demographic details, health history, knowledge and awareness of malaria and hepatitis, and access to healthcare services. Additionally, blood samples were collected for laboratory analyses to confirm the presence of malaria parasites and hepatitis viruses, ensuring a robust and reliable dataset.

The involvement of the Otunsha Foundation played a crucial role in community engagement and trust-building, fostering a collaborative environment for research. This partnership facilitated access to local resources and networks, enhancing the overall efficacy of the data collection process. Community health workers were trained to assist in outreach efforts, raising awareness about the study and encouraging participation among residents. The combination of longitudinal and cross-sectional methodologies within this study design allowed for a comprehensive understanding of the epidemiological trends of malaria and hepatitis within Lafia. By capturing both temporal and spatial data, the research aims to inform public health strategies and interventions tailored to the specific needs of the community, ultimately contributing to improved health outcomes in Lafia, Nasarawa State.

Ethical clearance

Ethical clearance for this study was obtained through the Otunsha Foundation from the State's Ministry of Health. This approval process ensured that the research adhered to ethical standards and guidelines concerning human subjects, promoting the safety and rights of participants throughout the study. The ethical review involved a thorough examination of the research proposal, focusing on the methodologies employed, the potential risks and benefits to participants, and the measures implemented to protect their confidentiality and privacy such as anonymization of participant's data and informed consent. By collaborating with the Otunsha Foundation, a respected local organization, the research team was able to engage effectively with the community and build trust, which is vital in conducting health-related research.

Informed consent, a fundamental aspect of the ethical framework, was obtained from all participants through a signed consent form, before signing, the participants were provided with detailed information regarding the study's objectives, procedures, and any potential risks involved. Participants were assured that their participation was entirely voluntary and that they had the right to withdraw from the study at any time without facing any repercussions. Participants who didn't understand the English language were communicated to in Hausa Language (the predominant language of this area) and their responses were translated back to the English language by the trained field assistants. Furthermore, the research team committed to maintaining the confidentiality of all data collected, ensuring that personal information was anonymized and securely stored. Regular monitoring and adherence to ethical guidelines were maintained throughout the duration of the study, reinforcing the research team's commitment to conducting the study responsibly and ethically. Semi-structured questionnaires were administered after explaining the details of the study and procedure.

Inclusion and exclusion criteria

In conducting this study, specific inclusion and exclusion criteria were established to ensure the selection of appropriate participants and to enhance the validity of the findings. These criteria served as guidelines for identifying individuals who were eligible to participate in the research.

Inclusion Criteria included individuals residing within the Lafia East section of Lafia Local Government Area. Participants were required to be aged 18 years and older, as this age threshold allowed for informed consent and ensured that participants could fully comprehend the nature of the study and their involvement in it. Additionally, individuals who had been diagnosed with malaria or hepatitis B and C viruses at any point prior to the study were included, as their experiences and insights were essential for understanding the local burden of these diseases. Furthermore, participants who were willing to provide informed consent and actively engage in the study were also eligible.

Exclusion Criteria comprised several factors to maintain the integrity of the study. Individuals who were not residents of Lafia or those who had recently traveled outside the region were excluded to avoid confounding variables associated with geographical variations in disease prevalence. Additionally, participants with severe co-morbidities that could complicate their health status or influence the outcomes of the study were not included. This exclusion extended to individuals with immunosuppressive conditions or those undergoing treatments that could significantly alter their immune responses. Pregnant or breastfeeding women were also excluded from participation to minimize potential risks to both maternal and child health. Lastly, individuals who were unable to provide informed consent due to cognitive impairments or other reasons were not considered eligible for the study.

Sample size

Determination of sample size

Sample size was determined using this formula; $n = Z^2 P q/d^2$.

Where n = desired sample size.

Z = standard and normal deviation usually set at 1.96 or approximately 2.0 which correspond to 95% (0.05) confidence level.

P = proportion in the target population estimated to have the particular characteristics.

q = 1.0-p.

d = degree of accuracy usually set at 0.05 (source: Research Methodology, Prof. (Mrs). Araoye).

The sample size was determined in view of the prevalence rate of 25.5% for malaria and hepatitis from previous studies carried out in Benue State, Nigeria [32]. Number of subjects who were studied in each group was calculated to be 200. An attrition rate of 10% was added to the number to arrive at the sample size.

The calculation was based on fisher's sample size formula [32].

$$N = \frac{Z^2 P(1-P)}{d^2}$$

N = minimum sample size,

Z = (1.96) constant mean deviate,

1 = constant.

P = local prevalence of similar previous study = 25.5%.

d = Degree of precision adopted for the study = 0.05.

$N = (1.96)^2 \times 0.25 \times 0.83/(0.05)^2 = 0.535$.

$N = 0.535/0.0025$.

$N = 224$.

Using attrition rate of 10%, we have 224/0.9 = 248.

Sample collection

Blood specimens were collected from individuals who visited the laboratory for testing and exhibited symptoms of malaria and hepatitis. The study population consisted of two hundred sixty-four participants (264), drawn from the Lafia community in Nasarawa State, Nigeria. These individuals included male and female patients of various ages, encompassing both adults and children. A total of 264 questionnaires were administered to adults seeking testing. The primary aim was to determine the prevalence rates of malaria and hepatitis, identify associated risk factors, and gather socio-demographic information from the participants [32].

Data collection and serological examination

Blood specimens (approximately 5 ml) were collected using sterile disposable syringes from the venous puncture site under aseptic conditions. All specimens were tested for malaria, hepatitis B surface antigen, and hepatitis C virus using rapid serological kits for malaria, HBsAg, and HCV (Global, Germany) [32]. The study was conducted over a six-month period from April to October 2024. All tests were performed in accordance with standard procedures and practices following the manufacturer's instructions.

Laboratory procedures for malaria testing

Blood samples (approximately 5 ml) were obtained intravenously with the assistance of hospital phlebotomists. The blood samples were transferred into an ethylenediaminetetraacetic acid (EDTA) tube to prevent coagulation. Two blood films were prepared from each sample: one thin and one thick. The thick and thin smears were made on clean, dry microscope glass slides and allowed to air-dry. The thin smear was fixed in methanol, and both smears were stained with 2% Giemsa (BDH Laboratory Supplies, Poole BH 15 ITD, England) according to standard protocols [32, 33–34].

The stained slides were examined under a microscope using oil immersion at 100x magnification. Staining and parasite counting were performed independently by two microscopists, with any discrepancies resolved by a senior microscopist to ensure quality control. The films were assessed for the presence of parasites, with a negative result indicating the absence of parasites after examining under 200 high-power fields of a microscope. Parasite density was quantified against 200 leukocytes, based on an assumed leukocyte count of 8000 cells/µl of blood [32]. The degree of parasite density was graded as mild (< 1000 parasites/µl), moderate (1000–9999 parasites/μl), or severe (≥ 10,000 parasites/μl), following the method described by Dawaski et al. (2016) [33].

The calculation for parasites per μl of blood was as follows:

Parasites/ul of blood = No. of asexual stages × 8000 leukocytes/200 leukocytes.

The malaria test procedure was carried out using the CareStart kit. The strip from the sealed foil pouch was gently removed, and the sample number was recorded on the strip and the cassette. Following this, 5 μl of whole blood was added into the "S" well, along with 60 μl of assay buffer. The result was read after 20 min and documented.

Interpretation of test results

The interpretation of test results for malaria, hepatitis B surface antigen, and hepatitis C virus is as follows [35–36]:

- **Positive Result**: The presence of two color bands is indicative of a positive result. This means that one band appears in the control area, and another band appears in the test area. This result suggests that the individual has tested positive for the specific disease being tested (malaria, HBsAg, or HCV).
- **Negative Result**: If only one band is visible, located in the control area, this indicates a negative result. In this case, the absence of a band in the test area suggests that the individual does not have the disease being tested for.
- **Invalid Test**: The test result is considered invalid if the control band does not appear at all. This situation indicates a potential error in the test procedure, such as improper handling or a malfunction of the test kit. In such cases, the test should be repeated to ensure accurate results.

These interpretations are crucial for determining the health status of individuals tested for malaria and hepatitis, guiding subsequent medical decisions and interventions [32].

Hepatitis B and Hepatitis C virus testing

Hepatitis B and hepatitis C virus testing was conducted using rapid test strips designed for the detection of hepatitis B surface antigen (HBsAg) and hepatitis C virus (HCV). These tests offer a quick and efficient way to diagnose infections, enabling timely medical intervention.

Sample collection

To obtain the necessary samples for testing, the skin over the tip of the middle or ring finger of each respondent was punctured with a sterile lancet. Prior to the puncture, the area was cleaned using an alcohol swab to minimize the risk of contamination. After puncturing, hanging drops of fingerstick whole blood were collected and allowed to fall onto the "specimen pad" of the HBsAg and HCV rapid test strips (manufactured by Abon Biopharm [Hangzhou] Co. Ltd., P. R. China). Following this, a drop of buffer solution was added to facilitate the testing process. The results were read at 15 min, in accordance with the manufacturer's instructions [32].

The test strips are designed to provide clear results, where the presence of two distinct colored lines indicates a positive result, while a single colored line appearing solely in the control region signifies a negative result. These rapid test strips exhibit high accuracy, with a sensitivity of 99.0% (ranging from 98.1 to 99.6%) and a specificity of 99.1% (ranging from 98.5 to 99.5%).

Laboratory procedure for Hepatitis B surface antigen testing

The testing for hepatitis B surface antigen (HBsAg) began with the careful removal of the test strip from its sealed foil pouch. The sample number was recorded on the strip for identification purposes. Next, two drops of whole blood were added into the designated "sample pad" of the test strip, followed by the addition of one drop of buffer solution. The result was evaluated after 15 min, allowing sufficient time for the red line to develop.

- **Positive Result**: A positive result for hepatitis B is indicated by the appearance of two color bands—one in the control area and one in the test area.
- **Negative Result**: The presence of only one band in the control area signifies a negative result.
- **Invalid Test**: If the control band does not appear, the test is deemed invalid, indicating that the test may need to be repeated to ensure accuracy.

Test procedure for Hepatitis C virus testing

Similarly, the procedure for testing for hepatitis C virus (HCV) followed the same initial steps. After removing the strip from the sealed foil pouch, the sample number was written on the strip. Two drops of whole blood were added into the "sample pad" of the test strip, and one drop of buffer was subsequently added. The results were read after 10 min, as this timeframe is optimal for the development of the red line.

- **Positive Result**: A positive result for hepatitis C is indicated by two color bands: one in the control area and another in the test area.

- **Negative Result**: A single band appearing only in the control area indicates a negative result.
- **Invalid Test**: As with the HBsAg test, if the control band does not appear, the test is considered invalid, and retesting is recommended.

These rapid tests for hepatitis B and C provide vital information about an individual's health status, enabling healthcare providers to make informed decisions regarding treatment and management of these viral infections.

Data collection via questionnaires

The data collection process employed a semi-structured questionnaire which was used previously in a study by Ademoyegun and Aremu (2024) and was designed to gather comprehensive demographic and medical information from all subjects involved in the study [32]. This questionnaire included a range of demographic variables such as age, sex, address, family size, marital status, ethnic group, source of water, educational status, and occupation. Age was recorded to capture the age distribution of respondents, while sex differentiated between male and female participants. The address helped identify the geographic distribution of participants, which also assisted in understanding community-level factors affecting health. Family size was assessed to understand household dynamics and potential influences on health and resource allocation. Marital status was examined to explore its impact on health behaviors and access to healthcare, and ethnic group was recorded to investigate potential cultural influences on health practices and disease prevalence. The source of water was included to evaluate the quality of water supply, crucial for understanding exposure to waterborne diseases. Educational status assessed the level of education, which may correlate with health literacy and access to health information, and occupation was documented to examine employment types, which can be linked to exposure risks and socioeconomic status.

In addition to demographic data, the questionnaire contained several medical-related inquiries aimed at uncovering risk factors and health behaviors. Questions regarding prophylaxis aimed to gather information about the use of preventive treatments for diseases. The use of insecticides was explored to understand exposure to vector control measures, particularly relevant for diseases such as malaria. Information on tribal marks or tattoos was included to examine cultural practices that might relate to health beliefs and behaviors. Questions regarding drug abuse were designed to identify potential substance abuse issues impacting health, while inquiries about alcohol consumption assessed lifestyle factors that could contribute to health risks. Blood transfusion history was documented to evaluate any previous transfusions that might be relevant for screening blood-borne infections. Information on previous hospitalization was collected to gather data on any significant past health issues requiring hospital care, while previous surgery was documented to provide context for current health status. Clinical details were also included to collect specific health-related information that could aid in understanding the respondents' medical backgrounds, and questions regarding any prophylaxis given aimed to identify preventive measures administered to the subjects.

Data analysis

Data collected through the questionnaires were meticulously tabulated and entered into a computer statistical package, specifically SPSS version 25.0, for analysis. This software is widely used in research for its robust statistical capabilities. The chi-square test was employed to determine associations between categorical variables, allowing for the examination of relationships and differences in the distributions of variables across different groups. Correlation coefficients were calculated to explore the strength and direction of relationships between continuous variables, providing insights into how closely related the variables are. Descriptive statistics, including frequencies and percentages, were used to summarize the data, giving an overview of the population characteristics and health behaviors.

Throughout the data analysis, a confidence level of 95% was maintained, with a significance threshold set at 0.05. This means that any p-value below 0.05 was considered statistically significant, indicating a less than 5% probability that the observed associations occurred by chance. This rigorous statistical approach ensures that the findings of the study are both valid and reliable, providing a solid foundation for drawing conclusions about the prevalence and risk factors associated with the diseases under investigation.

Results

The overall prevalence of malaria, Hepatitis B surface antigen (HBsAg), and Hepatitis C virus (HCV) was assessed in a study conducted in Lafia, Nasarawa State. The prevalence of malaria, HBsAg, and HCV was analyzed according to sex (Fig. 2). Among males, 26 out of 133 tested positive for malaria, resulting in a prevalence of 19.55%. In contrast, among females, 18 out of 131 tested positive, yielding a prevalence of 13.74%. The Chi-square test results indicated no significant difference between genders (χ^2 = 1.455, $p = 0.228$) for malaria. For HCV, the overall prevalence was 4.5%, with 8 males (6.02%) and 4 females (3.05%). Again, no significant difference was found (χ^2 = 1.333, $p = 0.248$). For HBsAg, the overall prevalence was 15.5%, with 22 males (16.54%) and

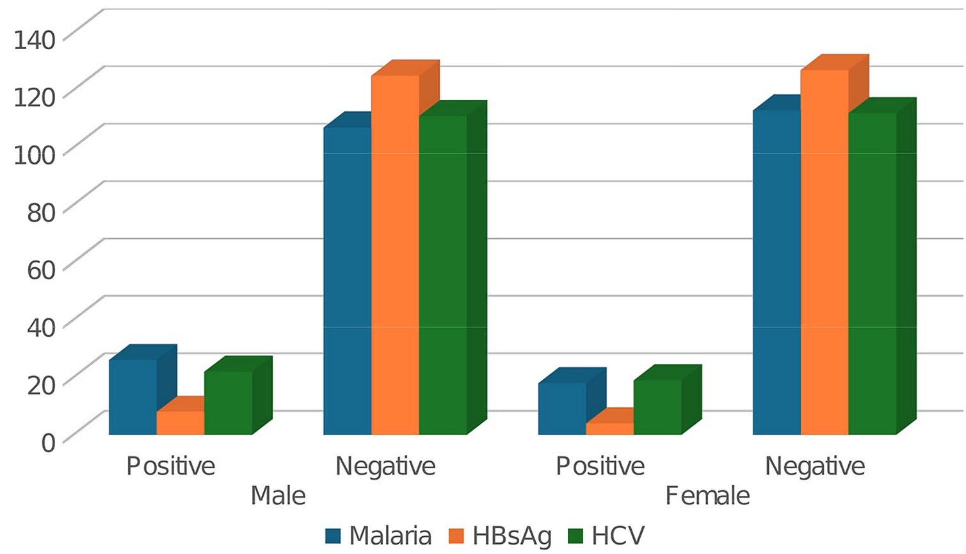

Fig. 2 Prevalence of Malaria, HBsAg and HCV according to Sex in Lafia, Nasarawa State

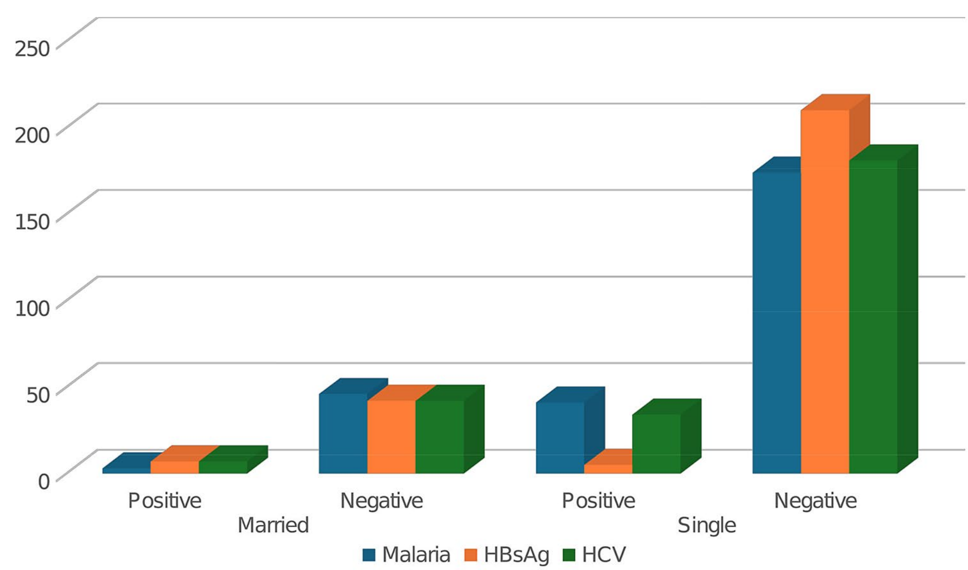

Fig. 3 Prevalence of malaria, HBsAg and HCV according to marital status

19 females (14.50%), showing no significant difference as well (χ^2 = 0.220, p = 0.639).

Figure 3 presents the prevalence of these conditions according to marital status. Among married individuals, 3 out of 49 tested positive for malaria, resulting in a prevalence of 6.1%, while among single individuals, 41 out of 215 tested positive (19.1%). This difference was statistically significant (χ^2 = 4.018, p = 0.045). For HCV, the prevalence was 14.3% among married individuals (7 out of 49) and only 2.3% among single individuals (5 out of 215), indicating a significant difference (χ^2 = 12.53, p = 0.000). The prevalence of HBsAg was similar among both marital statuses, with 7 out of 49 married individuals (14.3%) and 34 out of 215 single individuals (15.8%), showing no significant difference (χ^2 = 0.060, p = 0.806).

Figure 4 explores the prevalence of malaria, HBsAg, and HCV according to income level. Among low-income individuals, 38 out of 234 tested positive for malaria (16.2%), while 6 out of 26 middle-income individuals tested positive (23.1%). The Chi-square results showed no significant difference (χ^2 = 0.062, p = 0.803). For HCV, 10 out of 234 low-income individuals (4.3%) tested positive, while 2 out of 26 middle-income individuals (7.7%) tested positive, again with no significant difference (χ^2 = 0.207, p = 0.649). For HBsAg, 37 out of 234 low-income individuals (15.8%) tested positive, while 4 out of 26 middle-income individuals (15.4%) tested positive, showing no significant difference as well (χ^2 = 0.460, p = 0.498).

Table 1 summarizes the prevalence of malaria, HBsAg, and HCV by age. Among children aged 0–8 years, the

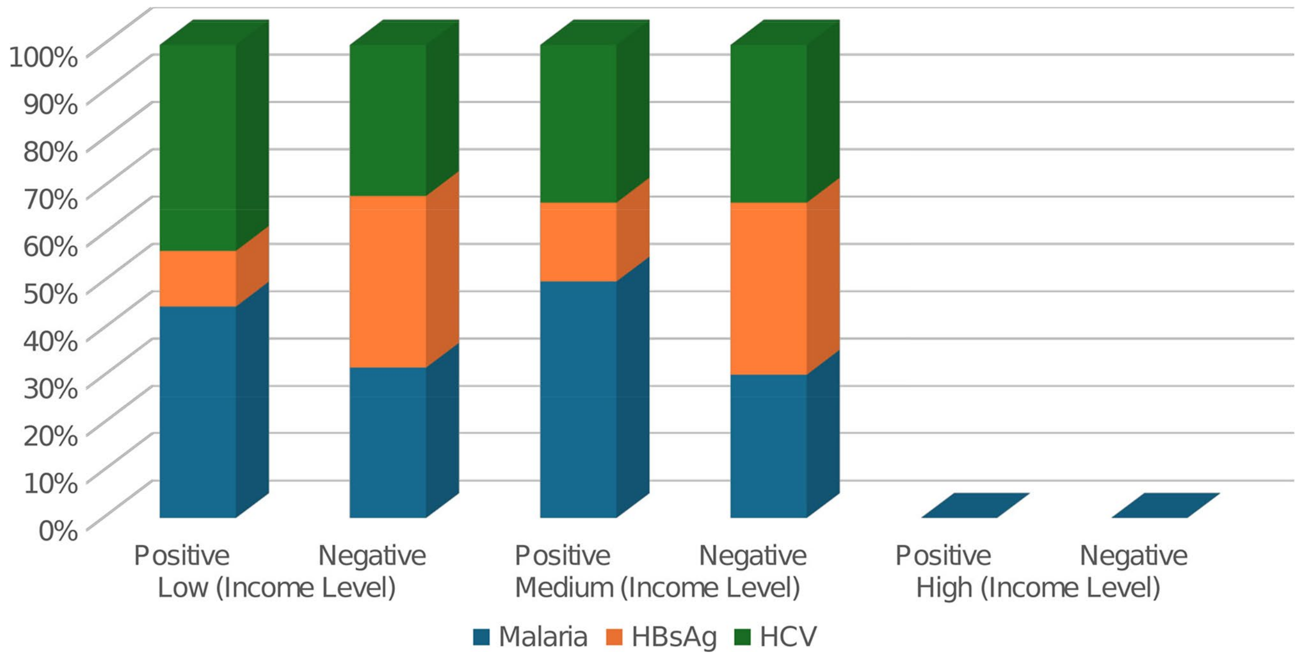

Fig. 4 Prevalence of malaria, HBsAg and HCV according to income level

Table 1 Prevalence of Malaria, HBsAg and HCV according to age in Lafia, Nasarawa State

Age (years)	Conditions		
	Malaria (MP) ($n=44$)	HCV ($n=12$)	HBsAg ($n=41$)
0–8 ($n=71$)	9 (20.5%)	1 (8.3%)	9 (22%)
9–17 ($n=80$)	23 (52.3%)	-	16 (39%)
18–29 ($n=43$)	6 (13.6%)	2 (16.7%)	7 (17.1%)
30–44 ($n=35$)	3 (6.8%)	4 (33.3%)	5 (12.2%)
45 and above ($n=35$)	3 (6.8%)	5 (41.7%)	4 (9.8%)
Chi-Square (χ^2)	7.14	20.77	0.74
p-value	0.129	**0.00035***	0.946

*values are significant at $p<0.05$

prevalence of malaria was 20.5% (9 out of 71), while in the age group 9–17 years, the prevalence increased to 52.3% (23 out of 80). In the 18–29 age group, 6 out of 43 tested positive (13.6%), and for ages 30–44, the prevalence was 6.8% (3 out of 35). Among individuals aged 45 and above, the prevalence remained at 6.8% (3 out of 35). The Chi-square results indicated no significant differences for malaria across age groups (χ^2 = 7.14, $p=0.129$). For HCV, the highest prevalence was found in the 30–44 age group (33.3%, 4 out of 35), while the lowest was among individuals aged 9–17, with no reported cases. The Chi-square analysis revealed a significant difference across age groups (χ^2 = 20.77, $p=0.00035$). The prevalence of HBsAg did not show significant differences across age groups (χ^2 = 0.74, $p=0.946$).

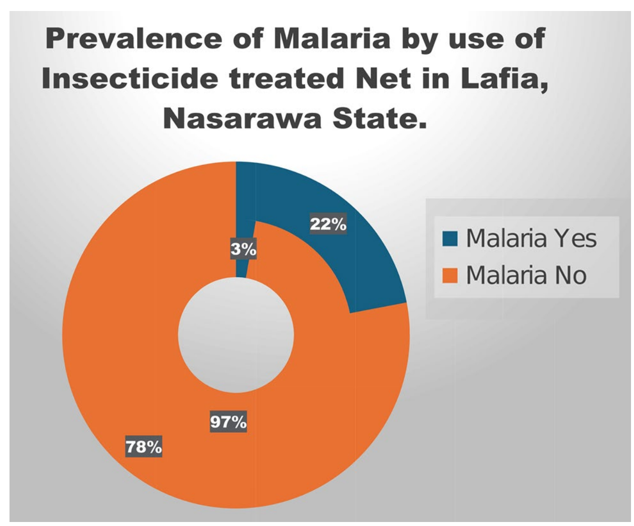

Fig. 5 Prevalence of malaria by use of Insecticide treated Net in Lafia, Nasarawa State

Prevalence rates of Hepatitis B, Hepatitis C and Malaria in Lafia, Nasarawa State

Figure 5 illustrates the prevalence of malaria based on the use of insecticide-treated nets (ITNs). Among individuals who used nets, only 2 out of 73 (4.5%) tested positive for malaria, compared to 42 out of 191 (95.5%) who did not use nets. The results showed a highly significant difference (χ^2 = 12.74, $p=0.00036$). Table 2 presents the prevalence of malaria based on clinical manifestations. Among individuals who reported a history of fever, 30 out of 44 tested positive for malaria (68.2%), while only 14 out of 220 who did not have a history of fever tested

Table 2 Prevalence of Malaria by clinical manifestation in Lafia, Nasarawa State

Clinical manifestation	Malaria		Chi-Square (χ^2)	*p*-value
	Yes (*n* = 44)	No (*n* = 220)		
History of Fever/Fever	30 (68.2%)	14 (6.4%)	96.49	< 0.001*
Previous hospitalization	3 (6.8%)	41 (18.6%)	2.89	0.089
Body pain	13 (29.5%)	31 (14.1%)	5.24	0.022*
joint pain	21 (47.7%)	23 (10.5%)	34.04	< 0.001*
Yellow coloration	3 (6.8%)	41 (18.6%)	2.89	0.089
Headache	17 (38.6%)	27 (12.3%)	16.50	< 0.001*
Loss of appetite	2 (4.5%)	42 (19.1%)	4.59	0.032*
Stomach pain	-	44 (20%)	9.17	0.002*
Vomiting	7 (15.9%)	37 (16.8%)	0.00	1.000
Blurred vision	18 (40.9%)	26 (11.8%)	20.30	< 0.001*

*values are significant at $p < 0.05$

positive (6.4%). This result was highly significant (χ^2 = 96.49, $p < 0.001$). Other significant clinical manifestations included joint pain (χ^2 = 34.04, $p < 0.001$) and headache (χ^2 = 16.50, $p < 0.001$).

Table 3 outlines the risk factors associated with the prevalence of HBsAg, HCV, and malaria in the study area. Regarding sex, among males, 22 tested positive for HBsAg, while 111 were negative, resulting in a crude odds ratio (COR) of 1.17 (95% CI: 0.60–2.28) with a Chi-square value of 0.213 ($p = 0.644$). For HCV, 8 males were positive, resulting in a COR of 2.03 (95% CI: 0.60–6.91) and a Chi-square value of 1.537 ($p = 0.215$). Among females, 19 tested positive for HBsAg, while 112 were negative, and 4 tested positive for HCV, with 127 negative.

In terms of age, for those aged 0–17 years, the COR for HBsAg was 1.20 (95% CI: 0.59–2.43) with a Chi-square value of 0.279 ($p = 0.597$). However, for HCV, the odds were significantly lower in this age group (COR = 0.062, 95% CI: 0.008–0.488, $p = 0.033$). For malaria, the COR was significantly higher at 2.26 (95% CI: 1.11–4.61, $p = 0.022$).

The vaccination status showed no positive cases among vaccinated individuals, while all unvaccinated individuals tested negative for HBsAg, HCV, and malaria. Marital status indicated that among singles, 34 had HBsAg positive results, leading to a COR of 1.13 (95% CI: 0.47–2.72, $p = 0.730$). The COR for HCV was significantly lower at 0.143 (95% CI: 0.043–0.472, $p = 0.005$), while for malaria, it was higher at 3.61 (95% CI: 1.07–12.18, $p = 0.041$).

The use of mosquito nets showed that 12 out of 73 net users tested positive for HBsAg, yielding a COR of 1.10 (95% CI: 0.53–2.29, $p = 0.782$). For HCV, the odds were lower at 1.33 (95% CI: 0.39–4.57, $p = 0.343$). Notably, among non-net users, the COR for malaria was significantly lower at 0.10 (95% CI: 0.024–0.43, $p = 0.001$).

The clinical manifestations were assessed, with 5 out of 51 individuals with symptoms testing positive for HBsAg, resulting in a COR of 0.53 (95% CI: 0.20–1.43, $p = 0.269$). For HCV, 3 out of 51 symptomatic individuals tested positive (COR = 1.42, $p = 0.336$), and for malaria, the odds were lower at 0.37 (95% CI: 0.13–1.09, $p = 0.099$). Correlations between various factors, such as sex, age, vaccination status, marital status, income level, water source, use of mosquito nets, and clinical manifestations, were analyzed using Pearson correlation coefficients, revealing significant relationships among several variables.

This analysis examines the correlation between various socio-demographic factors—such as sex, age, HBsAg (Hepatitis B surface antigen), HCV (Hepatitis C virus), malaria parasite (MP), vaccination status, marital status, income level, water source, use of mosquito nets, and clinical manifestations—within a cohort of 264 patients in Lafia, Nasarawa State. The table provides Pearson correlation coefficients and significance values that illuminate the relationships between these variables (Table 3).

The relationship between sex and the prevalence of malaria is highlighted by a significant negative correlation between male sex and MP (Pearson Correlation = -0.139, $p = 0.024$). This suggests that male patients may have a lower likelihood of malaria infection compared to female patients. This finding could indicate behavioral or biological factors affecting susceptibility, such as differing exposure to mosquito bites or differences in healthcare-seeking behavior.

When analyzing age, a significant positive correlation with HCV (Pearson Correlation = 0.218, $p < 0.001$) was observed, indicating that older individuals are more likely to exhibit higher prevalence rates of hepatitis C. The weak negative correlations with HBsAg (Pearson Correlation = -0.051, $p = 0.405$) and MP (Pearson Correlation = -0.113, $p = 0.066$) were not statistically significant, suggesting that age may play a more critical role in the prevalence of HCV compared to HBsAg and malaria.

With regard to HBsAg, a significant correlation with clinical manifestations (Pearson Correlation = 0.173, $p = 0.005$) indicates that patients who test positive for HBsAg are more likely to exhibit clinical symptoms. This relationship is crucial for clinical practice, as it highlights the need for healthcare professionals to monitor HBsAg-positive individuals closely for the development of symptoms that may require intervention.

The analysis reveals a positive correlation between HCV and marital status (Pearson Correlation = 0.223, $p < 0.001$), suggesting that married individuals may have higher rates of hepatitis C. This finding could be indicative of shared risk factors or socioeconomic conditions that increase the likelihood of transmission within marital units. Furthermore, a correlation between marital status and income level (Pearson Correlation = 0.121, $p = 0.049$) suggests that married individuals may possess

Table 3 Risk factors associated with the prevalence of Hepatitis B, Hepatitis C and Malaria in Lafia, Nasarawa State

Factors	HbsAg					HCV					MP				
	Yes	No	COR (95% CI)	X^2	*p*- Value	Yes	No	COR (95% CI)	X^2	*p*- Value	Yes	No	COR (95% CI)	X^2	*p*-Value
Sex															
Male	22	111	1.17 (0.60–2.28)	0.213	0.644	8	125	2.03 (0.60–6.91)	1.537	0.215	26	107	1.53 (0.79–2.94)	1.708	0.191
Female	19	112				4	127				18	113			
Age (years)															
0–17 years	25	126	1.20 (0.59–2.43)	0.279	0.597	1	150	0.062 (0.008–0.488)	4.519	0.033	32	119	2.26 (1.11–4.61)	5.217	0.022
18– above	16	97				11	102				12	101			
Vaccinated															
Yes	0	7				0	7				0	7			
No	0	257				0	257				0	257			
Marital status															
Single	34	181	1.13 (0.47–2.72)	0.119	0.730	5	210	0.143 (0.043–0.472)	8.043	0.005	41	174	3.61 (1.07–12.18)	4.183	0.041
Married	7	42				7	42				3	46			
Use of Mosquito net															
Yes	12	61	1.10 (0.53–2.29)	0.077	0.782	4	69	1.33 (0.39–4.57)	0.897	0.343	2	71	0.10 (0.024–0.43)	10.718	0.001
No	29	162				8	183				42	149			
Clinical Manifestation															
Yes	5	46	0.53 (0.20–1.43)	1.221	0.269	3	48	1.42 (0.37–5.43)	0.927	0.336	4	47	0.37 (0.13–1.09)	2.725	0.099
No	36	177				9	204				40	173			

higher economic stability, which could influence access to healthcare and preventive measures.

The variable of income level exhibits a significant negative correlation with the use of mosquito nets (Pearson Correlation = -0.144, $p = 0.020$). This finding indicates that individuals with higher incomes are less likely to utilize mosquito nets. Such a trend raises important questions about the perception and accessibility of preventive measures against malaria among different income groups, underscoring the need for tailored public health campaigns to promote protective behaviors across socioeconomic strata.

The correlation between the water source and MP (Pearson Correlation = 0.149, $p = 0.015$) highlights the significance of environmental factors in malaria transmission. This positive correlation suggests that the source of water could significantly influence malaria infection rates, reinforcing the established connection between environmental conditions and disease dynamics.

Moreover, the significant negative correlation between the use of mosquito nets and MP (Pearson Correlation = -0.231, $p < 0.001$) demonstrates that individuals who use mosquito nets are less likely to be infected with malaria. This result supports the efficacy of mosquito nets as a critical preventive measure against malaria and emphasizes the importance of promoting their usage as part of public health initiatives.

Finally, the significant correlations between clinical manifestations and both HBsAg (Pearson Correlation = 0.173, $p = 0.005$) and MP (Pearson Correlation = 0.194, $p = 0.001$) suggest that patients with these conditions are likely to present with more pronounced clinical symptoms. This observation underscores the necessity for healthcare providers to maintain vigilance in assessing and monitoring patients with known infections, facilitating timely diagnosis and management.

The correlation analysis presented in Table 4 examines the relationships between the prevalence of Hepatitis B surface antigen (HBsAg), Hepatitis C virus (HCV), and malaria (MP), alongside various risk factors within the study population in Lafia, Nasarawa State. The analysis reveals significant associations for malaria and several risk factors. A negative correlation exists between sex and malaria (r = -0.139, $p = 0.024$), indicating that male participants are more likely to test positive for malaria than female participants. In contrast, no significant correlation was found between sex and the prevalence of HBsAg ($r = 0.035$, $p = 0.575$) or HCV ($r = 0.002$, $p = 0.979$).

Age is positively correlated with HCV ($r = 0.218$, $p = 0.000$), suggesting that older individuals in the sample are more likely to be HCV-positive. However, there was no significant correlation between age and HBsAg (r = -0.051, $p = 0.405$) or malaria (r = -0.113, $p = 0.066$). Vaccination status showed no significant correlations with HBsAg (r = -0.071, $p = 0.252$), HCV (r = -0.036, $p = 0.560$), or malaria (r = -0.074, $p = 0.232$). Similarly, income level exhibited no significant correlation with any of the three conditions assessed, with values close to zero for each association.

In terms of marital status, a significant positive correlation was found with HCV ($r = 0.223$, $p = 0.000$), suggesting that married individuals may have higher rates of HCV compared to singles. Conversely, a negative correlation with malaria was noted (r = -0.135, $p = 0.028$), indicating that singles may be more susceptible to malaria. Water source was positively correlated with malaria ($r = 0.149$, $p = 0.015$), suggesting that individuals using borehole water might be at higher risk of malaria, while no significant correlation was found with HBsAg (r = -0.082, $p = 0.186$) or HCV ($r = 0.087$, $p = 0.157$).

The use of mosquito nets was associated with a negative correlation with malaria (r = -0.231, $p = 0.000$), indicating that using mosquito nets significantly reduces the risk of malaria infection. However, no significant correlation was found with HBsAg ($r = 0.015$, $p = 0.802$) or HCV ($r = 0.028$, $p = 0.654$). Lastly, clinical manifestations showed a significant positive correlation with both HBsAg ($r = 0.173$, $p = 0.005$) and malaria ($r = 0.194$, $p = 0.001$), suggesting that individuals presenting clinical symptoms are more likely to test positive for these infections. No significant correlation was observed with HCV (r = -0.031, $p = 0.617$).

Table 5 outlines the socio-economic and demographic characteristics of the study participants. A total of 264 patients were evaluated, with a nearly equal distribution between genders: 133 males (50.4%) and 131 females (49.6%). The age distribution indicates that the majority of participants were in the younger age brackets, with 71 individuals (26.9%) aged 0–8 years and 80 individuals (30.3%) aged 9–17 years, collectively representing a significant portion of the study population (57.2%). The representation of adults was lower, with 43 individuals (16.3%) aged 18–29 years, and both the 30–44 and 45 and above age groups consisting of 35 individuals each (13.3%).

In terms of marital status, a substantial majority of participants were single, comprising 215 individuals (81.4%), while married individuals made up 49 (18.6%). This disparity suggests a predominance of single individuals in the population under study. Regarding income levels, the data reflects a significant prevalence of low-income participants, with 234 individuals (88.6%). Middle-income participants accounted for 26 (9.8%), and only 4 individuals (1.5%) were classified as high-income, underscoring the socio-economic challenges faced by the population in Lafia.

The source of water for the participants was predominantly borehole water, utilized by 236 individuals (89.4%),

Table 4 Correlation analysis of socio-demographic factors, Malaria, HBsAg, and HCV prevalence among patients in Lafia, Nasarawa State

		Sex	Age	HBsAg	HCV	MP	Vaccinated	Marital status	Income_level	Water source	Use of mosquito net	Clinical manifestation
Sex	Pearson Correlation	1	0.035	0.035	0.002	−0.139*	0.025	0.072	0.003	−0.176**	−0.004	0.101
	Sig. (2-tailed)		0.574	0.575	0.979	0.024	0.688	0.245	0.967	0.004	0.951	0.101
	N	264	264	264	264	264	264	264	264	264	264	264
Age	Pearson Correlation	0.035	1	−0.051	0.218**	−0.113	0.048	0.659**	0.093	0.243**	−0.034	0.001
	Sig. (2-tailed)	0.574		0.405	0.000	0.066	0.442	0.000	0.133	0.000	0.578	0.985
	N	264	264	264	264	264	264	264	264	264	264	264
HBsAg	Pearson Correlation	0.035	−0.051	1	−0.043	0.005	−0.071	−0.016	−0.035	−0.082	0.015	0.173**
	Sig. (2-tailed)	0.575	0.405		0.483	0.940	0.252	0.791	0.566	0.186	0.802	0.005
	N	264	264	264	264	264	264	264	264	264	264	264
HCV	Pearson Correlation	0.002	0.218**	−0.043	1	−0.049	−0.036	0.223**	0.022	0.087	0.028	−0.031
	Sig. (2-tailed)	0.979	0.000	0.483		0.430	0.560	0.000	0.723	0.157	0.654	0.617
	N	264	264	264	264	264	264	264	264	264	264	264
MP	Pearson Correlation	−0.139*	−0.113	0.005	−0.049	1	−0.074	−0.135*	0.009	0.149*	−0.231**	0.194**
	Sig. (2-tailed)	0.024	0.066	0.940	0.430		0.232	0.028	0.885	0.015	0.000	0.001
	N	264	264	264	264	264	264	264	264	264	264	264
Vaccinated	Pearson Correlation	0.025	0.048	−0.071	−0.036	−0.074	1	0.042	0.131*	0.014	0.003	−0.024
	Sig. (2-tailed)	0.688	0.442	0.252	0.560	0.232		0.492	0.033	0.819	0.956	0.693
	N	264	264	264	264	264	264	264	264	264	264	264
Marital_status	Pearson Correlation	0.072	0.659**	−0.016	0.223**	−0.135*	0.042	1	0.121*	0.098	0.053	−0.061
	Sig. (2-tailed)	0.245	0.000	0.791	0.000	0.028	0.492		0.049	0.111	0.388	0.321
	N	264	264	264	264	264	264	264	264	264	264	264
Income_level	Pearson Correlation	0.003	0.093	−0.035	0.022	0.009	0.131*	0.121*	1	−0.084	−0.144*	0.088
	Sig. (2-tailed)	0.967	0.133	0.566	0.723	0.885	0.033	0.049		0.171	0.020	0.153
	N	264	264	264	264	264	264	264	264	264	264	264
Water_source	Pearson Correlation	−0.176**	0.243**	−0.082	0.087	0.149*	0.014	0.098	−0.084	1	−0.206**	−0.006
	Sig. (2-tailed)	0.004	0.000	0.186	0.157	0.015	0.819	0.111	0.171		0.001	0.923
	N	264	264	264	264	264	264	264	264	264	264	264
Use of Mosquito net	Pearson Correlation	−0.004	−0.034	0.015	0.028	−0.231**	0.003	0.053	−0.144*	−0.206**	1	−0.091
	Sig. (2-tailed)	0.951	0.578	0.802	0.654	0.000	0.956	0.388	0.020	0.001		0.139
	N	264	264	264	264	264	264	264	264	264	264	264
Clinical Manifestation	Pearson Correlation	0.101	0.001	0.173**	−0.031	0.194**	−0.024	−0.061	0.088	−0.006	−0.091	1
	Sig. (2-tailed)	0.101	0.985	0.005	0.617	0.001	0.693	0.321	0.153	0.923	0.139	
	N	264	264	264	264	264	264	264	264	264	264	264

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 5 Correlation analysis for Malaria, HBsAg, HCV patients and risks factors in Lafia, Nasarawa State

Factors	Conditions		
	HBsAg	HCV	MP
Sex	0.035 ($p = 0.575$)	0.002 ($p = 0.979$)	−0.139* ($p = 0.024$)
Age	−0.051 ($p = 0.405$)	0.218** ($p = 0.000$)	−0.113 ($p = 0.066$)
Vaccinated	−0.071 ($p = 0.252$)	−0.036 ($p = 0.560$)	−0.074 ($p = 0.232$)
Marital status	−0.016 ($p = 0.791$)	0.223** ($p = 0.000$)	−0.135* ($p = 0.028$)
Income level	−0.035 ($p = 0.566$)	0.022 ($p = 0.723$)	0.009 ($p = 0.885$)
Water source	−0.082 ($p = 0.186$)	0.087 ($p = 0.157$)	0.149* ($p = 0.015$)
Use of Mosquito net	0.015 ($p = 0.802$)	0.028 ($p = 0.654$)	−0.231** ($p = 0.000$)
Clinical Manifestation	0.173** ($p = 0.005$)	−0.031 ($p = 0.617$)	0.194** ($p = 0.001$)

* Correlation is significant at the 0.05 level (2-tailed)

** Correlation is significant at the 0.01 level (2-tailed)

Table 6 Socio-economic and demographic characteristics of the patients

Variable	Frequency	Percentage (%)
Gender		
Male	133	50.4
Female	131	49.6
Age (years)		
0–8	71	26.9
9–17	80	30.3
18–29	43	16.3
30–44	35	13.3
45 and above	35	13.3
Marital Status		
Single	215	81.4
Married	49	18.6
Income level		
Low	234	88.6
Middle	26	9.8
High	4	1.5
Source of Water		
Borehole	236	89.4
Tap	26	9.8
Well	2	0.8

while 26 (9.8%) used tap water, and only 2 (0.8%) relied on well water. This information highlights the reliance on borehole water as a primary water source within the community, which may have implications for health outcomes related to water quality and accessibility. Overall, the socio-economic and demographic characteristics presented in this study provide essential context for understanding the prevalence and risk factors associated with malaria, Hepatitis B, and Hepatitis C in Lafia, Nasarawa State, highlighting potential areas for public health interventions and resource allocation (Table 6).

Discussion

The research conducted in Lafia, Nasarawa State, provides critical insights into the prevalence of malaria, Hepatitis B surface antigen (HBsAg), and Hepatitis C virus (HCV), situating these findings within a global context. The malaria prevalence in this study was reported at 16.7%, reflecting its endemic nature in sub-Saharan Africa, where environmental conditions such as high temperatures, significant rainfall, and high vector density create favorable conditions for transmission. Compared to other studies conducted in hyperendemic regions, the prevalence observed in Lafia is lower than rates reported in other parts of Nigeria, including 82.72% (426/515), 64.9% (227/350), 51% (51/100), 41.6% (106/255), and 35.7% (419/1173) [37]. Similarly, higher rates have been documented in India (22–26%, 36.6%), Malaysia (33.6%, 410/1222) [38], Kenya (28%, 325/1158), Rwanda (22.8%, 175/769) [39], East Wollega, Ethiopia (21.2%, 26,679/125,917; 49.4%, 156/316) [40, 41], North-Western Ethiopia (32.6%, 33,434/102,520; 29%, 61/210) [42], South Ethiopia (28.1%, 91/324) [43], East Shewa, Ethiopia (20.5%, 170/830; 25%, 204/810) [44], and Arba Minch, South Ethiopia (22.1%, 60/271) [45]. In contrast, the malaria prevalence in Lafia exceeds rates reported in West Ethiopia (10.2%, 51/498) [46], South Ethiopia (6.1%, 28/461) [47], and North-West Ethiopia (7.3%, 296/4,077; 3.5%, 26/735) [48].

These variations can likely be attributed to differences in geographic location, climatic conditions, and demographic factors among study populations. The findings from this study underscore the persistent public health burden of malaria in many parts of Nigeria and across sub-Saharan Africa. As such, the information obtained can inform the development of targeted strategies to control and prevent malaria, ultimately reducing its impact on affected communities [49]. There is also a stark contrasts with much lower prevalence rates in non-endemic regions. For instance, in Southeast Asia, targeted vector control measures and early diagnosis have reduced malaria prevalence to less than 5% in most countries, while in Europe and North America, malaria is largely limited to imported cases, with near-zero prevalence among local populations [50–52].

The overall prevalence of HBsAg in this study was 15.5%, aligning with the World Health Organization's classification of sub-Saharan Africa as a region of high hepatitis B endemicity, where prevalence rates typically exceed 8%. The prevalence of HBsAg recorded in our study was higher than the 1.5% reported in Southwestern Nigeria by Enitan, et al. [52] and lower than the 16.67%

and 13.3% reported by Ekuma, et al. [53] and Pennap et al. [54] respectively, in North central Nigeria.

The prevalence rate of HBsAg observed in this study aligns closely with findings from research conducted at Guhalla Primary Hospital in Ethiopia, which reported a prevalence of 14% [55], and a study in Gondar among patients attending the serology laboratory at Gondar University Hospital, which recorded a rate of 14.4% [56]. However, this rate is notably higher than findings from other studies of diverse study population in different parts of Ethiopia such as 3.0-10.9% [57–68], and blood donors in Eritrea (2.6% and 2.0%) [69, 70]. Comparatively, another study in Northern Nigeria reported a 10.9% prevalence rate among blood donors [71], while a study in Japan found an even lower rate of 0.8% [72].

Conversely, the HBsAg prevalence observed in this study is lower than rates reported in certain high-risk populations. For instance, studies recorded over 22–57.5% among blood donors and among patients with chronic hepatitis [73–75]. In another part of Nigeria, a prevalence of 18.6% was reported among blood donors [76]. These discrepancies may be attributed to factors such as differences in sample size, geographic locations, detection methods, cultural practices, and variations in risk factors. The endemicity of HBV is often influenced by the primary mode of transmission, which can vary widely between regions. Additionally, differences in research design and assay techniques used to detect HBV infection likely contribute to the observed variations in prevalence rates. However, these rates are significantly higher than those reported in regions like North America and Europe, where widespread vaccination programs have reduced prevalence to less than 1% [77]. Notably, the prevalence in Lafia is also higher than that observed in some parts of Asia, where national immunization programs have achieved significant progress, particularly in countries like Japan and South Korea, where prevalence now stands at around 2–3% [78–81]. This comparison underscores the critical role of universal vaccination in reducing hepatitis B prevalence globally and highlights the urgent need to strengthen immunization efforts in high-prevalence areas such as Lafia [80, 82, 83].

HCV prevalence in Lafia was reported at 4.5%, a rate that, while relatively low compared to HBsAg, remains concerning given the global disparities in HCV burden. In sub-Saharan Africa, HCV prevalence generally ranges from 2 to 5%, placing the findings from this study within expected regional parameters. A study conducted in southeastern Nigeria among the outpatients attending the general hospital recorded 4.39% [84], and 12.9% in Nigeria among urban and rural communities 12.9% [85], and in Pakistan among the patients reporting in surgical OPD 10.8% [86], in contrast this study lower than study conducted in Addis Ababa among CLD patients 57.5% [87], and in Pakistan among patients seeking hospital care 23.5% [87]. However, these rates are higher than those reported in North America and Western Europe, where effective blood screening and safer medical practices have reduced prevalence to less than 1% [88–91]. Conversely, certain regions, such as Central Asia and Egypt, report much higher HCV prevalence rates, often exceeding 10%, due to historical challenges with unsafe medical practices and limited access to antiviral therapies [92]. The prevalence observed in Lafia is therefore indicative of an intermediate burden that necessitates improved diagnostic, preventive, and therapeutic measures to mitigate the long-term impact of HCV on public health.

When contextualized globally, the prevalence rates for all three conditions in Lafia reflect the substantial public health challenges faced by regions with limited access to healthcare resources, widespread poverty, and high infectious disease burdens [32]. While these rates are comparable to those reported in other parts of sub-Saharan Africa, they starkly contrast with the low prevalence observed in high-income countries, where robust healthcare systems and comprehensive public health interventions have drastically reduced the burden of these diseases. For malaria, the key differences are driven by the presence or absence of endemicity, while for HBsAg and HCV, disparities stem largely from the degree of access to vaccination, screening, and treatment programs. These comparisons highlight the pressing need for targeted global efforts to address the health inequities that underpin such disparities and to prioritize resource allocation to regions like Lafia, where the burden of preventable and treatable diseases remains disproportionately high [93].

Furthermore, this study conducted in Lafia, Nasarawa State, provides valuable insights into the prevalence of malaria, Hepatitis B surface antigen (HBsAg), and Hepatitis C virus (HCV) across various demographic categories, shedding light on patterns of disease distribution and potential areas for intervention. The results revealed no significant differences in the prevalence of these conditions based on sex. While males showed slightly higher prevalence rates for malaria, HBsAg, and HCV compared to females, these differences were not statistically significant. This lack of disparity aligns with findings from similar studies in other regions, suggesting that sex-based variations in infectious disease prevalence are often minimal, though they may vary depending on environmental, behavioral, or physiological factors [94–95].

Marital status appeared to play a more pronounced role, particularly in the prevalence of malaria and HCV. Single individuals demonstrated a significantly higher prevalence of malaria compared to married individuals. This difference could reflect variations in living conditions, exposure risks, or access to preventive measures, as married individuals may benefit from shared resources or a greater focus on household health [32]. For HCV, the higher prevalence observed among married individuals could be linked to cumulative exposure over time, possible transmission within households, or other social factors not directly explored in this study [32]. In contrast, the prevalence of HBsAg remained similar between married and single individuals, indicating that the risk factors driving hepatitis B infection might be less influenced by marital status and more associated with universal factors such as vaccination coverage, perinatal transmission, or shared environmental exposures [32].

Interestingly, income level did not significantly influence the prevalence of any of the three conditions. Both low-income and middle-income individuals exhibited comparable rates of malaria, HBsAg, and HCV [32]. This finding suggests that in this context, socioeconomic disparities may not play a decisive role in determining exposure or susceptibility. It could also reflect the pervasive nature of these infections in the region, where environmental factors, such as vector density for malaria or limited access to healthcare services, may uniformly affect individuals regardless of income level. This uniformity underscores the need for widespread, community-based interventions rather than income-targeted programs.

Age emerged as a critical factor, particularly in the prevalence of malaria and HCV. The highest prevalence of malaria was observed among children aged 9–17 years, which could be attributed to their increased outdoor activities, reduced use of protective measures like bed nets, or differences in immunity compared to younger children [96–99]. In contrast, the prevalence of malaria was lowest among adults aged 30–44 and those aged 45 and above, likely reflecting acquired immunity or reduced exposure. For HCV, the highest prevalence was recorded in the 30–44 age group, suggesting that cumulative exposure to risk factors such as unsafe medical practices, occupational hazards, or lifestyle behaviors might contribute to the increased burden. Notably, no HCV cases were reported among individuals aged 9–17, highlighting a potential age-related variation in exposure or vulnerability [100]. Despite these differences for malaria and HCV, the prevalence of HBsAg did not vary significantly across age groups. This consistency could indicate that hepatitis B infections, often acquired perinatally or in early childhood in endemic regions, result in a stable distribution of chronic carriers across all age brackets.

The findings of this study have important implications for public health strategies. The higher prevalence of malaria among single individuals and children aged 9–17 years underscores the need for targeted interventions, such as enhanced vector control measures, increased access to insecticide-treated bed nets, and community education programs tailored to these vulnerable groups. For HCV, the significant differences observed by marital status and age warrant further investigation into underlying transmission dynamics. Efforts to reduce the burden of HCV should focus on strengthening infection control practices, improving access to testing and treatment, and addressing behavioral and social factors that may contribute to increased risk in certain populations. Meanwhile, the consistent prevalence of HBsAg across demographics highlights the critical importance of universal vaccination programs, routine screening, and public awareness campaigns to prevent hepatitis B transmission and manage chronic carriers effectively.

The socioeconomic landscape of the study population revealed a predominance of low-income individuals, with 88.6% categorized as low-income. This finding reflects a common trend in malaria-endemic regions where poverty exacerbates the risk of infection [32]. Access to healthcare, preventive measures, and awareness about malaria and viral hepatitis are often limited in low-income settings, contributing to higher infection rates.

The use of borehole water as the primary water source among participants (89.4%) may raise concerns about the quality of water and its implications for health. Previous studies have highlighted the relationship between water quality and health outcomes in Nigeria, noting that inadequate access to clean water is a significant risk factor for infectious diseases. The correlation observed between the source of water and malaria prevalence in our study suggests that individuals relying on potentially contaminated water sources might be at increased risk of malaria, aligning with findings from other research that emphasizes the importance of clean water access in controlling malaria transmission [32].

Furthermore, the significant positive correlation between clinical manifestations and both HBsAg and malaria highlights the relationship between symptom presentation and infection status. Clinical manifestations often prompt individuals to seek medical attention, leading to diagnosis and subsequent management of infections. This finding supports previous research that underscores the importance of clinical symptoms in guiding the diagnosis and treatment of malaria and viral hepatitis [32].

Overall, this study underscores the diverse factors influencing the prevalence of malaria, HBsAg, and HCV in Lafia, Nasarawa State. It highlights the need for tailored public health strategies that address the unique vulnerabilities of different population groups. By focusing on both targeted interventions and universal measures, such as vaccination and health education in Lafia municipal as well as suburbs, public health efforts can effectively reduce the burden of these infections and improve health outcomes in the community [1, 4–5].

To effectively combat the dual burden of malaria and viral hepatitis in Lafia, Nasarawa State, and similar regions, a multifaceted approach is required. Strengthening preventive measures is critical, with community-based interventions such as the widespread use of insecticide-treated mosquito nets (ITNs) and environmental management strategies to reduce malaria transmission in Lafia metropolis [31, 32]. Public education campaigns should encourage consistent net usage and active community participation in vector control initiatives. Equally important is the enhancement of vaccination programs targeting hepatitis [2–3, 21–23, 30]. Health authorities must focus on increasing awareness of and accessibility to hepatitis vaccinations, particularly among high-risk populations. Public health campaigns should be designed to educate communities on the benefits of vaccination while ensuring that services are readily available [101].

Improving water quality and access in the town is another crucial step. Investments in infrastructure to provide safe, clean water sources, coupled with community health initiatives promoting water sanitation and hygiene practices, are essential to mitigate health risks associated with contaminated water [8–11]. Furthermore, integrating health services to address both malaria and hepatitis within primary healthcare settings can enhance efficiency, streamline resources, and improve patient outcomes. Such integrated programs should prioritize screening and treatment to deliver holistic care [32].

Additional research is needed to explore the epidemiology of malaria and viral hepatitis, focusing on identifying risk factors and barriers to healthcare access in diverse demographic groups. This will enable the design of evidence-based interventions. Lastly, policy advocacy must address the socioeconomic determinants of health, such as poverty and low health literacy. Through poverty alleviation, education, and health literacy programs, public health efforts can achieve sustainable improvements [32]. By implementing these strategies, stakeholders can work towards reducing the health burden in Lafia and similar regions, ultimately advancing public health outcomes in Nigeria.

Limitations of the study

A significant limitation of this study is its cross-sectional design, which captures data at a single point in time. This approach, while useful for estimating prevalence, does not provide insights into temporal trends or causative relationships between variables. For instance, the study cannot determine whether specific risk factors directly influence the observed prevalence rates or track the progression of infections over time, thereby limiting its utility for assessing the impact of public health interventions or predicting future trends. The study's geographic focus is another constraint, as it is limited to a specific population in Lafia, Nasarawa State, Nigeria. While this localized approach provides detailed insights into the study area, it limits the generalizability of the findings to other regions with different demographic, cultural, and environmental conditions. Variations in factors such as healthcare infrastructure, access to medical services, and community health behaviors may result in different prevalence rates elsewhere.

Additionally, the study did not deeply investigate confounding factors such as socioeconomic status, education level, or occupation, which could provide a more nuanced understanding of the factors influencing disease transmission. Behavioral or cultural practices, which are often critical in determining exposure and susceptibility to infections like malaria, HBV, and HCV, were also not explored. Including these variables could have enriched the analysis and offered more actionable insights. Other potential limitations in its methodology include reliance on self-reported data, which may introduce recall or reporting bias, and the use of rapid diagnostic tests, which could result in variability or reduced accuracy. Despite standard diagnostic techniques being used, potential diagnostic inaccuracies remain a limitation. Factors such as human error, suboptimal sample handling, or inherent limitations of the diagnostic tools could result in false positives or negatives, potentially skewing the reported prevalence rates and influencing the overall interpretation of the findings.

The study also did not explore the genetic variability of the pathogens, which can significantly affect disease prevalence and severity. This omission is particularly relevant in genetically diverse populations like that of Nigeria, where such variability may influence transmission dynamics and health outcomes. Lastly, the study lacked a longitudinal component, preventing an assessment of the impact of seasonal variations on malaria prevalence or the influence of public health campaigns on HBV and HCV rates over time. Future research incorporating a longitudinal design could provide a more dynamic understanding of disease patterns and their drivers. The broader socio-economic impact of these infections on affected communities, which is crucial for resource allocation and policy advocacy, was also not addressed.

Overall, while the study offers valuable prevalence data, it highlights the need for further research to address these limitations. Future studies should consider longitudinal designs, expand their geographic scope, and include more comprehensive analyses of confounding factors to provide a more holistic understanding of these public health challenges.

Conclusion

This study provides valuable insights into the concerning association between malaria, HBsAg, and HCV among patients in Lafia, Nasarawa State, Nigeria. The study's findings point to a troubling burden of infectious diseases, which is often exacerbated by socioeconomic vulnerabilities and limited healthcare resources in the region. This complex interplay between malaria, HBsAg, and HCV emphasizes the urgent need for an integrated public health approach. Efforts to address these infections must go beyond individual disease management and include strategies that tackle the underlying socioeconomic factors, such as improving income, access to clean water, and healthcare services. A multifaceted approach is necessary to effectively reduce the prevalence of malaria and viral hepatitis, particularly in low-income populations. This could involve community-based interventions, increased access to vaccination, and public health education campaigns that address both the diseases and the social determinants that facilitate their spread. Addressing these interconnected health challenges will contribute to a healthier, more resilient community.

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Author contributions
DOA, AM, SOA, YDT, SOI, and AAB conceptualized and designed the study and contributed to drafting and revising the manuscript. DOA, AM, SOA, YDT, SOI, and AAB contributed to data collection, and manuscript review, DOA, AM, SOA, YDT, SOI, and AAB participated in study design, and critically reviewed the manuscript for important intellectual content. DOA, AM, SOA, YDT, SOI, and AAB assisted with the literature review, data visualization, and preparation of initial manuscript drafts, All authors provided methodological expertise, and contributed significantly to manuscript revisions. All authors supported data acquisition and provided feedback on the manuscript drafts. All authors contributed to the manuscript structure, final proofreading, and editing for clarity and coherence; all authors have read and approved the final manuscript.

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Data availability
The datasets generated and analyzed during the current study are not publicly available due to privacy considerations of the participants but are available from the corresponding author upon reasonable request.

Code availability
Not applicable.

Declarations

Ethics approval and consent to participate
Not applicable.

Consent for participation
Consent for participation was collected from all study participants prior to their involvement in the research. Participants were informed of the study's purpose, procedures, and potential risks. They were assured that their participation was voluntary and that their personal information would remain confidential. Written consent was obtained before data collection began.

Consent for publication
The participant was informed that by signing the consent form, they would grant permission for the publication of data collected from their participation in the study on the prevalence of malaria, HBsAg, and HCV in Lafia, Nigeria, and the role of socio-demographic factors. They were assured that the findings might be published in scientific journals or presented at conferences, and that all data would remain anonymized with no identification of the participant. They were also informed that they could withdraw their consent for publication at any time without affecting their participation in the study.

Competing interests
The authors declare no competing interests.

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