

Spatio-Temporal Patterns of Hepatitis B in Gombe State, Nigeria

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ABSTRACT

Hepatitis B virus (HBV) continues to pose a significant public health challenge in Nigeria, with the country ranking among the highest in global HBV prevalence. Despite national efforts toward prevention and control, the spatial and temporal dynamics of HBV infection remain poorly understood in several regions, particularly in north-eastern states like Gombe. This study aimed to examine the spatial distribution and temporal trends of Hepatitis B across selected Local Government Areas (LGAs) in Gombe State between 2019 and 2023. Data were obtained from hospital records, field surveys, and laboratory-confirmed cases. Using geospatial analysis tools within a GIS framework, the study mapped HBV cases across urban and rural areas to identify geographic hotspots and trend variations over the study period. The findings revealed that rural LGAs such as Nafada and Balanga consistently recorded higher HBV prevalence than urban centers like Gombe LGA. Spatial clustering analysis showed persistent hotspots in the southeastern and northern regions of the state. Temporal analysis indicated fluctuating infection rates, with a notable peak in 2021 and a slight decline in 2023, potentially linked to public health outreach variability. The study concludes that HBV distribution in Gombe State exhibits clear spatial inequalities and time-based variations, influenced by socio-economic and infrastructural factors. It recommends targeted intervention strategies, expanded rural vaccination campaigns, and regular spatio-temporal surveillance to reduce HBV transmission and its associated health burden in Gombe State.

Keywords: Hepatitis B, Spatio-temporal patterns, Geographic distribution, Gombe State, Nigeria, Health disparities, viral hepatitis.

1. INTRODUCTION

Hepatitis B virus (HBV) infection remains a major global public health issue, affecting an estimated 296 million people worldwide as of 2019, with over 1.5 million new infections reported each year (World Health Organization [WHO], 2021). The disease, which attacks the liver, can cause both acute and chronic conditions, with long-term complications such as liver cirrhosis and hepatocellular carcinoma. Globally, HBV is responsible for about 820,000

deaths annually, and its burden is especially severe in low- and middle-income countries, notably in sub-Saharan Africa and parts of Asia (Aliyuet *al.*, 2021; WHO, 2021). Among these, Nigeria has one of the highest HBV prevalence rates in the world, estimated at 11% nationwide, putting over 20 million people at risk for serious liver-related complications (Federal Ministry of Health [FMoH], 2016).

Despite the introduction of HBV immunization into Nigeria's national immunization schedule in 2004 and the availability of effective vaccines and antiviral treatments, hepatitis B continues to spread, particularly in underserved and rural communities where health education, vaccination coverage, and routine testing remain inadequate (Ajuwon *et al.*, 2021). While considerable research has been done to document prevalence rates across Nigeria, most studies rely on hospital-based or blood donor data, which may not reflect true population-wide trends, especially in geographically diverse and socioeconomically heterogeneous areas (Enitan *et al.*, 2019; Baleghaet *et al.*, 2021).

Geographic Information Systems (GIS) and spatio-temporal analysis are increasingly recognized as vital tools for understanding the patterns, distribution, and drivers of infectious diseases like HBV. Mapping disease distribution over time and space enables public health planners to identify high-risk zones, evaluate intervention effectiveness, and optimize resource allocation (Barbosa *et al.*, 2021). Spatio-temporal analysis also helps in

required for targeted disease control efforts (Abdulrazaq, 2025).

This study, therefore, aims to analyze the spatial and temporal patterns and distribution of hepatitis B in Gombe State from 2019 to 2023. By applying geospatial tools and trend analysis, the research seeks to uncover high-prevalence zones, temporal fluctuations, and rural-urban disparities, thereby providing evidence-based insights for more effective public health interventions.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

Gombe State is located in the northeastern geopolitical zone of Nigeria and lies between latitudes 9°30' and 12°30' North and longitudes 8°45' and 11°45' East (see Figure 1). It shares boundaries with Borno to the northeast, Yobe to the north, Adamawa to the southeast, Bauchi to the west, and Taraba to the south. Covering an area of approximately 20,265 square kilometers, Gombe State serves as a transitional zone between the savannah and Sahel ecological belts, characterized

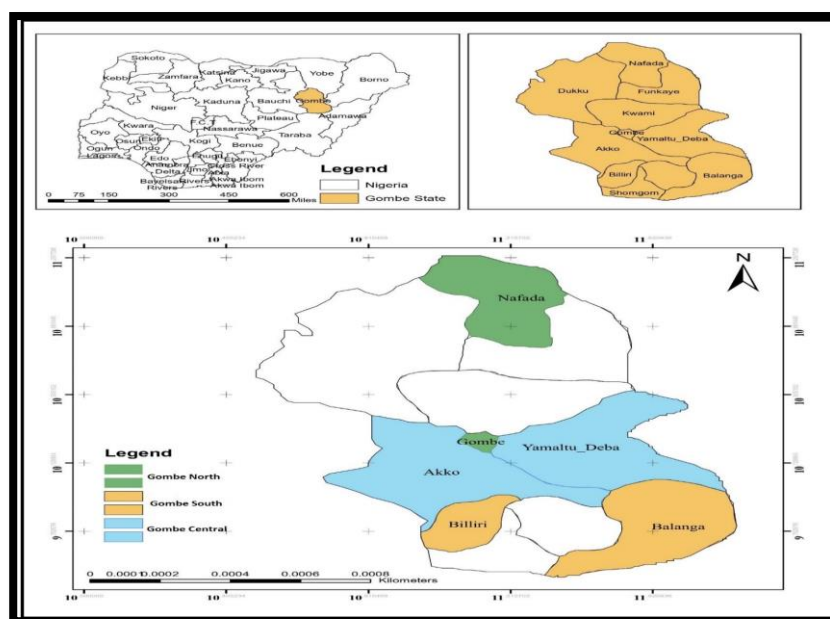


Figure 1: Map of the Study Area

uncovering hidden patterns in disease transmission and determining the impact of socio-demographic, environmental, and infrastructural factors on infection dynamics.

Gombe State, located in northeastern Nigeria, represents a region with limited epidemiological data on HBV despite evident vulnerability. The state's unique mix of rural and urban settings, coupled with disparities in healthcare access, public health infrastructure, and awareness levels, makes it an important case for localized investigation. Previous research has rarely addressed the geographic and temporal variability of hepatitis B in Gombe, creating a critical gap in knowledge

by a mixture of grasslands and sparse tree cover. The state has 11 Local Government Areas (LGAs) and is divided into three senatorial districts: Gombe Central, Gombe North, and Gombe South.

According to the National Population Commission, the projected population of Gombe State in 2023 is approximately 3.6 million people. The population is unevenly distributed, with significant rural-urban disparities. Major urban centers include Gombe (the state capital), Kumo, Bajoga, and Billiri, while large portions of the population reside in rural settlements like Nafada, Balanga, and Dukku. These rural areas are often characterized by limited access to healthcare infrastructure, poor road networks, and

lower literacy levels, which collectively affect healthcare-seeking behaviors and disease outcomes. The diverse topography and population distribution in Gombe State make it a critical region for analyzing the dynamics of infectious diseases such as hepatitis B. Mobility between rural and urban areas is frequent due to commercial activities and migration, creating pathways for disease transmission. Urban areas like Gombe metropolis have better access to health services, vaccination centers, and public health campaigns. In contrast, rural regions face significant challenges, including understaffed health facilities, a lack of cold-chain infrastructure for vaccines, and low awareness levels about hepatitis B transmission and prevention. These disparities underscore the importance of conducting a spatial and temporal analysis of hepatitis B across different parts of Gombe State. Understanding how HBV prevalence varies geographically and over time is essential for designing targeted interventions, prioritizing healthcare resource allocation, and ultimately reducing the disease burden in the state.

2.2 Study Design

This study employed a retrospective, mixed-method approach to investigate the spatio-temporal distribution of Hepatitis B Virus (HBV) in Gombe State, Nigeria, between 2019 and 2023. The retrospective design enabled the use of existing health records to track trends over time, while the mixed-method component combined quantitative geospatial data with qualitative insights from health officials and community reports to enhance contextual understanding.

2.3 Data Sources

This study adopted a purposive and stratified sampling approach to examine the spatio-temporal distribution of Hepatitis B Virus (HBV) in Gombe State between 2019 and 2023. Purposive sampling was used to select six Local Government Areas (LGAs) (Gombe, Akko, Nafada, Balanga, Billiri, and Yamaltu-Deba) based on their geographic spread, population characteristics, availability of health facilities, and reported burden of HBV cases. This ensured adequate representation of urban, semi-urban, and rural settings, which is essential for spatial comparison and hotspot identification. Within each selected LGA, stratified sampling was applied to categorize health facilities and cases by location (urban/rural), gender, and year of diagnosis. This stratification improved the reliability of comparisons across space and time and reduced sampling bias by ensuring that key sub-populations were proportionately represented. The sample size comprised 384 individuals who were tested for Hepatitis B surface antigen (HBsAg) during the study period, of which 105 cases (27.34%) were reactive, and 279 (72.66%) were non-reactive. The sample size was determined using

the Advisor Table (2006) sample size formula for prevalence studies, assuming a 95% confidence level, a 5% margin of error, and an estimated HBV prevalence of 50% to ensure maximum variability and statistical robustness. This sample size was considered adequate for spatial analysis, prevalence estimation, and trend assessment across the selected LGAs.

Quantitative data were obtained from hospital and primary healthcare records across the selected LGAs, including confirmed laboratory results, patient location (ward-level), year of diagnosis, and gender. To complement facility-based data and enhance data completeness, records from community health outreach programs, Gombe State Ministry of Health reports, and federal hepatitis surveillance databases were also reviewed.

The combined use of purposive and stratified sampling, along with an adequately powered sample size, strengthened the study's ability to capture spatial heterogeneity, identify HBV hotspots, and assess temporal trends across diverse geographic and socio-demographic contexts in Gombe State.. The dataset covered five years (2019–2023) and included:

1. **Location of cases:** Health facility-based addresses and ward-level details of patients.
2. **Annual trends:** Year-by-year breakdown of confirmed HBV cases within the study period.
3. **Gender and geographic breakdown:** Stratified data by sex (male/female) and by location (rural vs. urban LGAs).

Data from community health outreach programs, Gombe State Ministry of Health reports, and federal hepatitis surveillance records were also reviewed to complement facility-based data.

2.4 Spatial Tools

Geospatial analysis in this study was conducted using Geographic Information System (GIS) software (ArcGIS 10.x) to examine the spatial distribution, clustering, and hotspot patterns of Hepatitis B Virus (HBV) cases across selected Local Government Areas (LGAs) and wards in Gombe State.

Firstly, spatial data preparation and mapping were carried out by georeferencing administrative boundary shapefiles of Gombe State, LGAs, and wards. HBV case data obtained from health facilities were linked to their respective geographic locations using ward and LGA identifiers. This process enabled the creation of thematic (choropleth) maps showing the spatial distribution and intensity of HBV cases across the study area. The outcome of this step was the visualization of geographic variation in HBV prevalence, highlighting areas with higher and lower disease burden.

Secondly, hotspot analysis was performed using the Getis-Ord G_i^* statistic to identify statistically significant clusters of high (hotspots) and low (cold

spots) HBV prevalence. This tool measured the degree of spatial concentration of HBV cases by comparing local values to the overall study area. The outcome of the hotspot analysis was the identification of persistent high-risk zones, particularly in rural LGAs such as Nafada and Balanga, which consistently exhibited significantly higher HBV case concentrations.

Thirdly, spatial autocorrelation analysis was conducted using Global Moran's I to assess whether the spatial distribution of HBV cases was random, clustered, or dispersed. The Moran's I results indicated positive spatial autocorrelation, confirming that HBV cases were not randomly distributed but exhibited statistically significant clustering. This outcome validated the presence of localized transmission patterns and justified the identification of hotspots within the study area. Additionally, overlay analysis was applied to compare HBV distribution patterns with rural-urban classifications of LGAs. This enabled the assessment of spatial disparities in disease burden relative to settlement type and healthcare access. The outcome revealed a clear rural-urban divide, with higher HBV prevalence concentrated in rural wards characterized by limited healthcare infrastructure and lower vaccination coverage. Overall, the application of GIS tools in this study produced spatial outputs including distribution maps, hotspot maps, and clustering indices, which collectively enhanced understanding of the geographic dynamics of HBV transmission in Gombe State. These outcomes provided evidence-

based insights to guide targeted interventions, resource allocation, and spatially informed public health planning.

Results and discussion

3. RESULT

3.1 Spatial Distribution

Table 1 presents the spatial distribution of HBV in the 3 geopolitical zones consisting of 6 selected Local Government Areas and 12 wards.

Table 1: spatial distribution of HBV in the Three Geopolitical Zones

S/N	ZONE	LGAS	WARDS	Hepatitis B Result			
				Non-Reactive	%	Reactive	%
1	Gombe North	Gombe	Bajoga	37	13.26	3	2.86
			Nasarawo	13	4.66	8	7.62
		Nafada	Nafada Central	21	7.53	7	6.67
			Birin Fulani East	8	2.87	4	3.81
Sub Total				79	28.32	22	20.95
2	Gombe Central	Akko	Kumo Central	51	18.28	16	15.24
			Garko	18	6.45	9	8.57
		Deba	Deba	38	13.62	15	14.29
			Jagali North	12	4.30	8	7.62
Sub Total				119	42.65	48	45.71
3	Gombe South	Billiri	Billiri South	32	11.47	13	12.38
			Tanglang	9	3.23	5	4.76
		Balanga	Talasse	29	10.39	13	12.38
			Nyuwar	11	3.94	4	3.81
Sub Total				81	29.03	35	33.33
Grand Total				279	100	105	100.00

Source: Fieldwork, 2024

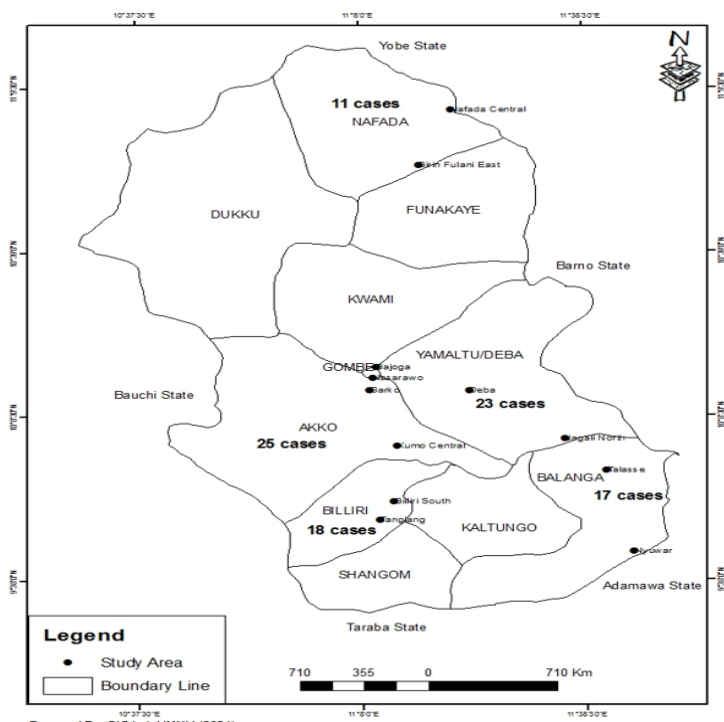


Figure 2: The spatial distribution of Hepatitis B Virus across LGAs

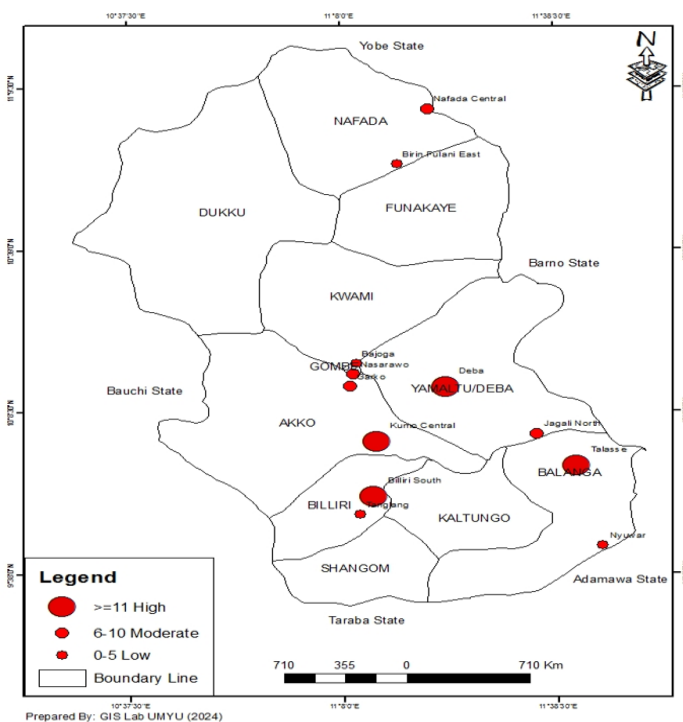


Figure 3: Hotspot Analysis of HBV across the Selected LGAs

The spatial analysis of Hepatitis B Virus (HBV) in Gombe State revealed distinct geographic disparities in prevalence across the six selected Local Government Areas (LGAs): Gombe, Akko, Balanga, Nafada, Billiri, and Yamaltu-Deba. The analysis of Hepatitis B test results across Gombe State revealed a 27.34% prevalence rate (105 Reactive cases out of 384 tests), with notable regional disparities. Gombe Central had the highest number of positive cases (48, 45.71%), while Gombe South exhibited the highest positivity rate (30.17%). Key high-burden areas included Kumo Central (16 cases), Deba (15 cases), and Billiri South & Talasse (13 cases each). In contrast, Gombe North had the lowest prevalence (21.78% positivity), with the fewest cases in Birin Fulani East and Nyuwar (4 each). These findings suggest the need for targeted vaccination and awareness campaigns, particularly in Gombe Central and Gombe South, to curb Hepatitis B transmission.

As shown in Figure 2, the spatial distribution of HBV cases varies significantly across the LGAs. Higher concentrations were observed in rural LGAs such as Nafada and Balanga, with prevalence rates

3.2 Hotspot Analysis

As shown in Figure 3, Persistent hotspot zones were identified primarily in the southeastern and northern regions of the state, particularly in rural wards of Balanga and Nafada. Spatial clustering using Moran's I confirmed statistically significant clusters of high HBV prevalence in these areas, indicating localized transmission foci with limited intervention. These hotspots often overlapped with areas lacking adequate healthcare facilities and HBV vaccination programs.

3.3 Urban-Rural Differences

As shown in Figure 4, the spatial patterns also reflect rural-urban disparities in healthcare infrastructure. Urban areas, such as Gombe metropolis, benefit from improved diagnostic services, more routine screening, and increased vaccination awareness, which contribute to lower case detection and prevalence. Conversely, rural regions face barriers including poor road access, health worker shortages, and cultural misconceptions about HBV transmission, which likely contribute to underreporting and increased transmission.

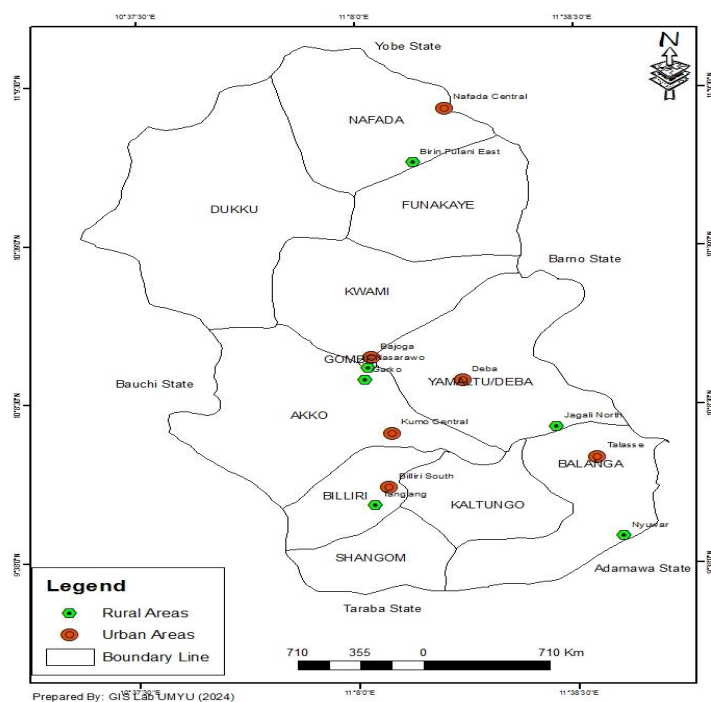


Figure 4: Urban-Rural Differentials across Selected LGAs

of 14.8% and 13.2%, respectively. In contrast, more urbanized LGAs like Gombe and Akko reported relatively lower prevalence rates, with Gombe LGA recording 8.7%. This suggests a rural-urban divide in HBV distribution, potentially linked to differences in healthcare access, awareness levels, and vaccination uptake.

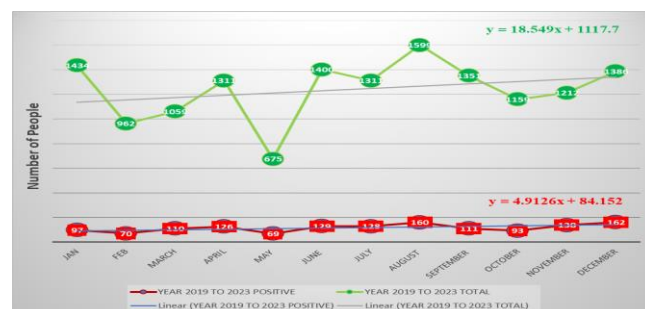


Figure 5: The Temporal pattern and distribution of Hepatitis B from 2019-2023

Source: Fieldwork, 2024



Figure 6: The Temporal Pattern of Hepatitis B Reactive Cases from 2019 to 2023

Source: Field Work, 2024

3.4 Temporal Patterns

The temporal analysis of HBV cases from 2019 to 2023, as shown in figure 5 revealed notable fluctuations in infection trends over the five-year period.

3.5 Annual Trends and Spikes

As illustrated in Figure 5 and Figure 6, the number of HBV reactive cases rose steadily from 2019 to

2021, peaking in 2021, before showing a mild decline through 2022 and 2023. This spike in 2021 may be attributed to enhanced testing efforts during state-wide health awareness campaigns or potential localized outbreaks in high-risk LGAs.

3.6 Trend Comparison (2019–2023)

Figure 7 shows a clear upward trend in the number of HBV tests conducted, suggesting increased public health engagement. However, Figure 8 indicates that while testing increased, the proportion of reactive (positive) cases peaked in 2021, then gradually declined. This drop may reflect improved vaccination and awareness initiatives introduced post-2021.

clustering in rural regions and significant temporal variations, with the highest burden observed in 2021 and greater prevalence among males. These findings underscore the importance of tailored public health responses that account for both geographic and temporal dynamics.

4. DISCUSSION

The spatial and temporal analysis of Hepatitis B Virus (HBV) distribution in Gombe State revealed distinct geographic clusters and time-based fluctuations that provide critical insight into the local dynamics of HBV transmission. The patterns observed, particularly the consistent hotspots in rural LGAs such as Nafada and Balanga, reflect a

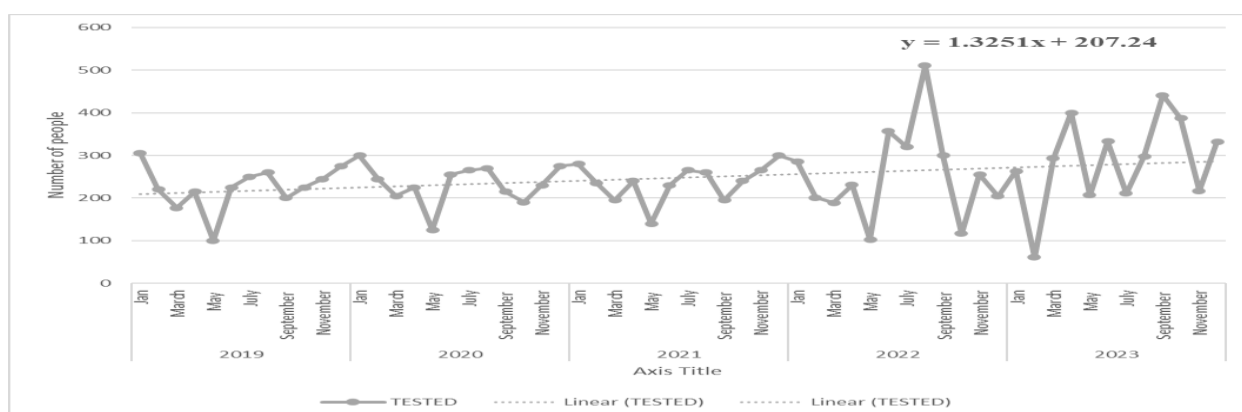


Figure 7: The Trend Analysis of Hepatitis B Testing from 2019 to 2023 Source: Field Work, 2024

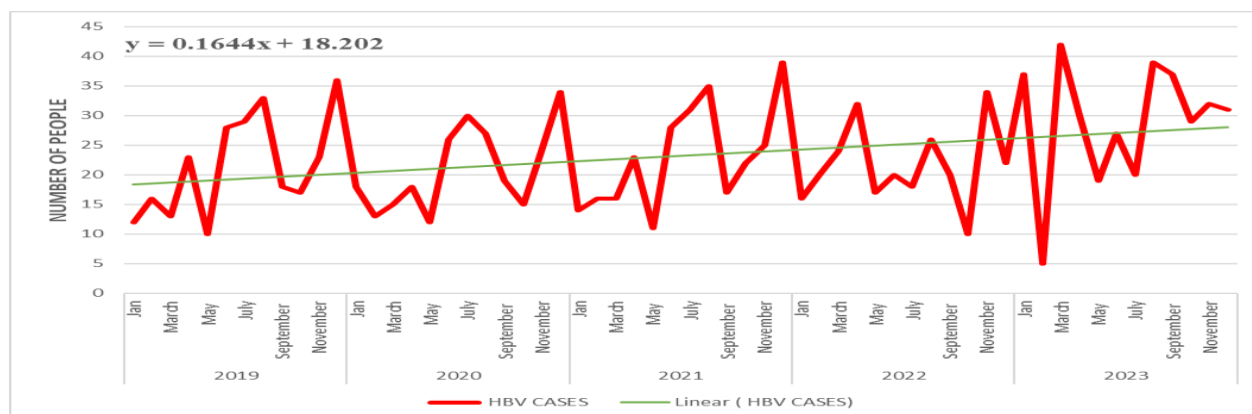


Figure 8: The Trend Analysis of Hepatitis B Cases in Gombe from 2019 to 2023 Source: Field Work, 2024

3.7 Gender-Specific Trends

Gender-disaggregated analysis in Figure 9 shows that males consistently recorded higher HBV prevalence than females across all years. This could be due to increased occupational exposure, lower healthcare-seeking behavior, or higher rates of risk behaviors among males. The consistent gender gap highlights the need for male-focused HBV awareness and screening programs in Gombe State. Overall, the results indicate that Hepatitis B in Gombe State is characterized by strong spatial

broader challenge common to many parts of Nigeria and Sub-Saharan Africa: the persistent inequalities in healthcare access, health literacy, and infrastructure.

4.1 Geographic Hotspots and Rural Disparities

The spatial clustering of HBV cases in Nafada and Balanga LGAs aligns with patterns commonly observed in rural communities where healthcare infrastructure is limited. These areas typically experience low vaccination coverage, inadequate public health education, and delayed diagnosis due

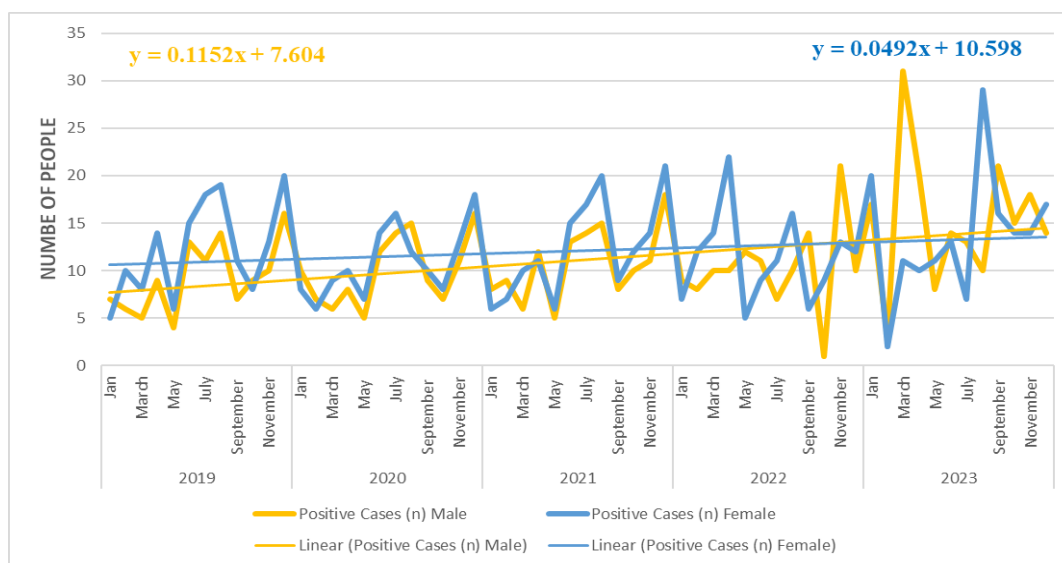


Figure 9: The Trend Analysis of Hepatitis B based on Gender from 2019 to 2023
Source: Field Work, 2024

to poor access to testing and treatment facilities (Ajuwon *et al.*, 2021). Rural isolation, compounded by transportation difficulties, understaffed clinics, and lack of trained health personnel, contributes to the silent spread of HBV in these communities. In addition, cultural misconceptions about the transmission of hepatitis B, such as beliefs that the virus spreads through casual contact or spiritual causes, further impede preventive behaviors and timely treatment (Enitan *et al.*, 2019).

This is consistent with findings by Barbosa *et al.* (2021) in rural Brazil and Baleghaet *al.* (2021) in northern Nigeria, both of which reported higher HBV prevalence in rural zones characterized by weak health systems and socioeconomic challenges. Similarly, a GIS-based study by Musa *et al.* (2023) in Bauchi State, adjacent to Gombe, found that HBV hotspots coincided with rural settlements lacking primary healthcare coverage and routine vaccination programs.

The time-series hotspot analysis of Hepatitis B Virus (HBV) cases in Gombe State reveals clear temporal evolution in the intensity, size, and continuity of hotspot zones between 2019 and 2023. Using the Getis-Ord G_i^* statistic, yearly hotspot maps were generated to assess how HBV clustering patterns changed over time across the selected LGAs and wards.

4.2 Evolution of HBV Hotspots Over Time (2019–2023)

The 2019 hotspot map shows isolated and scattered HBV hotspots, primarily concentrated in specific rural wards of Nafada and Balanga LGAs. These early hotspots were relatively small and discontinuous, indicating localized transmission pockets rather than widespread community transmission.

By 2020, the hotspot pattern expanded moderately, with increased clustering in the southern and southeastern parts of the state, particularly within Balanga and parts of Billiri LGA. The emergence of additional hotspot nodes suggests rising HBV detection and possible spillover into adjacent wards. The 2021 hotspot map represents a critical transition period. During this year, large, dense, and more continuous HBV hotspots emerged, forming distinct hotspot belts across the southern and central zones of the study area, including Balanga, Billiri, Akko, and parts of Yamaltu-Deba. The strong spatial clustering during this period reflects the peak HBV prevalence recorded in the temporal analysis and may be associated with increased testing, delayed diagnoses following COVID-19 disruptions, and intensified transmission in underserved rural communities.

In 2022, hotspot intensity remained high but became slightly fragmented. While major hotspot zones persisted in Nafada and Balanga, some wards showed reduced clustering, suggesting the early impact of vaccination campaigns, awareness programs, or improved access to diagnostic services. By 2023, the hotspot map shows a partial contraction of HBV hotspots, with fewer continuous belts and more localized clusters. Although persistent hotspots remained in rural wards of Nafada and Balanga, the overall spatial intensity declined compared to 2021. This pattern aligns with the observed reduction in HBV reactive cases during the later years of the study period.

The transition from isolated hotspots (2019) to continuous and intense hotspot belts (2021), followed by gradual fragmentation and decline (2022–2023), reflects changing disease dynamics influenced by healthcare access, public health

interventions, and temporal shifts in testing and surveillance.

4.3 HBV Hotspot Areas Identified (Persistent and Transitional)

Based on the year-by-year hotspot analysis, HBV hotspot areas were categorized into persistent hotspots and transitional hotspots:

Areas that consistently emerged as high-HBV hotspots across all years (2019–2023) include:

- a. Rural wards of Nafada LGA
- b. Southern and southeastern wards of Balanga LGA
- c. Selected rural pockets within Billiri LGA

These areas represent zones with sustained HBV transmission, likely driven by limited healthcare infrastructure, low vaccination coverage, and poor disease awareness.

Areas that transitioned from low or non-hotspot → hotspot status over time include:

- a. Central wards of Akko LGA
- b. Peri-urban expansion zones of Yamaltu-Deba
- c. Bordering wards between Gombe Central and Gombe South

The emergence of hotspots in these transitional areas suggests increasing population mobility, urban–rural interaction, and changing healthcare-seeking behavior, which may facilitate HBV spread beyond traditionally high-risk rural zones.

4.4 Interpretation and Public Health Implications

The strong clustering of HBV hotspots, particularly during the 2021 peak, indicates sustained and localized transmission dynamics, characteristic of regions with limited preventive healthcare services and delayed diagnosis. The gradual reduction and fragmentation of hotspots after 2021 suggest that targeted interventions may be yielding positive outcomes, although persistent rural hotspots highlight the need for sustained surveillance and intervention.

Overall, the time-series hotspot analysis provides critical evidence that HBV transmission in Gombe State is not static, but evolves spatially and temporally, reinforcing the importance of continuous spatio-temporal monitoring to support effective disease control strategies.

The identification of persistent HBV hotspots in rural LGAs such as Nafada and Balanga aligns closely with findings reported by Balegha *et al.* (2021) in northern Nigeria, who observed significantly higher HBV prevalence in rural communities with limited access to healthcare services and vaccination programs. Similarly, Musa *et al.* (2023), in a GIS-based study in neighboring Bauchi State, found that HBV hotspots were spatially concentrated in rural wards lacking adequate primary healthcare coverage. These parallels suggest that rurality, poor health

infrastructure, and low immunization uptake are consistent determinants of HBV clustering across northern Nigeria.

Beyond Nigeria, comparable spatial patterns have been reported in other endemic regions. Barbosa *et al.* (2021) demonstrated that HBV infections in rural Brazil showed statistically significant spatial clustering in areas with weak health systems, mirroring the positive spatial autocorrelation observed in this study. The consistency of these findings across different geographic contexts underscores the reliability of GIS-based approaches in identifying HBV transmission foci.

4.5 Urban-Rural Divide in Prevalence

In contrast, urban centers such as Gombe metropolis showed lower prevalence rates, likely due to better healthcare access, more frequent screening, and greater public awareness. Urban residents are more likely to be exposed to health education via media campaigns, school-based programs, and employer-based wellness screenings. This urban-rural disparity echoes national data, where urban populations tend to show better health-seeking behavior and more proactive disease prevention (WHO, 2021).

The lower HBV prevalence observed in urban LGAs such as Gombe and Akko supports national and regional evidence that urban populations benefit from better access to health information, screening services, and vaccination opportunities. Enitan *et al.* (2019) reported higher awareness and preventive practices related to HBV in urban Nigerian populations compared to rural dwellers. Likewise, the World Health Organization (2021) noted that urbanization is often associated with improved healthcare utilization, which contributes to lower undiagnosed infection rates. The rural–urban disparity observed in Gombe State therefore reflects broader structural inequalities documented in HBV epidemiology.

4.6 Temporal Patterns and Contributing Factors

The peak in HBV cases observed in 2021, followed by a gradual decline, coincides with a post-COVID-19 rebound in healthcare service utilization. During the early stages of the pandemic (2020), routine health services were disrupted due to lockdowns, fear of visiting clinics, and resource reallocation toward COVID-19 management (Aliyuet *et al.*, 2021). As restrictions eased and health campaigns resumed in 2021, more individuals accessed testing and vaccination services, resulting in a temporary spike in diagnosed cases.

The subsequent decline from 2022 to 2023 may reflect the impact of renewed vaccination efforts, particularly in hotspot areas where NGOs and local health authorities implemented outreach programs. This is similar to trends reported in Lagos and Kaduna, where temporal peaks in HBV prevalence

were followed by reductions attributed to targeted immunization drives and awareness campaigns (Adebowale *et al.*, 2022).

The temporal pattern identified in this study, with HBV cases peaking in 2021 followed by a gradual decline through 2023, is consistent with findings reported by Adebowale *et al.* (2022) in Lagos and Kaduna States. These authors linked similar temporal spikes to increased post-COVID-19 testing and renewed public health outreach activities. Aliyu *et al.* (2021) further emphasized that disruptions to routine health services during the COVID-19 pandemic led to delayed diagnoses, which later manifested as temporary increases in reported cases when services resumed. The temporal fluctuations observed in Gombe State, therefore, appear to reflect broader national and regional health system dynamics rather than isolated local anomalies.

4.7 Gender-Specific Trends

Across the five-year period, the higher prevalence of HBV among males is notable. This trend has been observed in several Nigerian and sub-Saharan studies and is often linked to occupational exposure (e.g., barbers, butchers, transport workers), lower likelihood of attending preventive health checks, and risk behaviors such as unprotected sex or tattooing (Oladejo *et al.*, 2022). Males may also underutilize healthcare services due to social stigma, economic constraints, or perceptions of invulnerability (Enitanet *et al.*, 2019).

The consistently higher HBV prevalence among males observed in this study corroborates findings from several Nigerian studies. Oladejo *et al.* (2022), using data from the Nigeria Demographic and Health Survey, reported significantly higher HBV infection rates among males, attributing this pattern to occupational exposure, lower health-seeking behavior, and engagement in high-risk practices. Similar male dominance in HBV prevalence has been reported across sub-Saharan Africa (Komas *et al.*, 2013), suggesting that gender-based behavioral and social factors play a critical role in HBV transmission dynamics.

4.8 Comparison with Other Regions

The patterns observed in Gombe align with similar findings across other Nigerian states and Sub-Saharan Africa. For example, Komaset *et al.* (2013) in the Central African Republic found HBV prevalence to be significantly higher in rural regions due to poor infrastructure and inadequate immunization coverage. Likewise, Ajuwonet *et al.* (2021) emphasized that in Nigeria, hepatitis B is more prevalent in areas where health literacy and access to services are limited, particularly in the northern and northeastern zones.

While national strategies such as the National Hepatitis Strategic Plan (2016–2020) have aimed to scale up HBV testing and vaccination, implementation has been uneven, especially in rural

and underserved regions like Gombe. This study underscores the need for location-specific data to drive policy and resource allocation, as a one-size-fits-all approach fails to account for the geographic and temporal variability of the disease.

The geographic hotspots and time-based fluctuations in HBV prevalence in Gombe State reveal deeper structural and systemic issues in rural healthcare delivery and public health education. These findings match broader national and regional trends and support the need for targeted, evidence-based interventions, especially in identified hotspot LGAs. Strategies should focus on rural outreach, culturally sensitive awareness campaigns, and ongoing vaccination programs, especially for high-risk groups.

Overall, the findings of this study are consistent with existing literature, reinforcing the understanding that HBV transmission is strongly influenced by geographic location, healthcare access, temporal health system disruptions, and gender-related behaviors. However, this study contributes uniquely by providing localized, spatio-temporal evidence for Gombe State, a region that has been underrepresented in previous HBV research. By integrating GIS-based spatial analysis with temporal trend assessment, this study extends existing knowledge and provides actionable insights for targeted intervention planning.

5. CONCLUSION

This study examined the spatio-temporal distribution of Hepatitis B Virus (HBV) across selected Local Government Areas (LGAs) in Gombe State, Nigeria, from 2019 to 2023. The findings revealed significant geographic disparities in HBV prevalence, with Nafada and Balanga LGAs emerging as persistent hotspots. These areas consistently recorded higher infection rates, largely due to their rural status, limited healthcare infrastructure, and reduced access to vaccination and public health education.

The temporal analysis showed that HBV infection rates fluctuated annually, peaking in 2021 before gradually declining through 2023. These trends likely reflect the impact of external factors such as the COVID-19 pandemic, subsequent health campaigns, and changes in health service accessibility. Notably, rural areas remained disproportionately affected throughout the study period, emphasizing the continued vulnerability of populations in underserved communities.

The study underscores the urgent need for targeted public health interventions in high-prevalence LGAs. These should include expanded vaccination coverage, localized education campaigns, and improved diagnostic capacity in rural areas. Furthermore, the fluctuating yearly trends highlight the importance of time-sensitive and sustained health programs, designed to respond promptly to emerging outbreaks and seasonal spikes.

Without such strategic, data-driven approaches, the burden of hepatitis B will persist in Gombe State, undermining broader public health goals and delaying progress toward national and global hepatitis elimination targets.

Recommendations

Based on the findings of this study, the following recommendations are proposed to improve the control and prevention of Hepatitis B Virus (HBV) in Gombe State:

1. **Expand HBV Surveillance Across Rural LGAs:** The state government, in collaboration with the Ministry of Health and partner organizations, should scale up routine HBV surveillance in rural areas such as Nafada and Balanga. These areas, identified as persistent hotspots, require intensified monitoring to detect emerging cases early, ensure timely reporting, and facilitate swift public health response.
2. **Conduct Regular Spatio-Temporal Mapping to Track Outbreaks:** Geospatial analysis tools should be institutionalized within public health systems to enable continuous mapping of HBV distribution and trends. Regular updates to spatial datasets will allow health authorities to visualize outbreak dynamics, evaluate intervention effectiveness, and allocate resources more efficiently based on evidence.
3. **Deploy Mobile Vaccination and Testing Units During Identified High-Risk Months:** Given the seasonal variations and annual spikes observed, particularly the surge in 2021, mobile health teams should be deployed strategically during high-risk periods to provide on-site testing, counseling, and vaccination services, especially in remote and underserved communities. This approach will help close the urban-rural gap in healthcare access and reduce transmission rates among high-risk groups.
4. **Scale Up Community-Based Health Education Programs:** The study identified widespread **misconceptions** about HBV transmission and prevention, especially in rural areas. Tailored health education campaigns should be designed to **correct misinformation**, promote safe practices, and encourage early testing. Engagement with community leaders, religious institutions, and local radio stations can improve reach and impact.
5. **Integrate Routine HBV Screening into Primary Healthcare Services:** Screening for HBV should become a **standard component** of antenatal care, blood donation, school health programs, and pre-employment medicals. Routine testing will increase case detection and reduce transmission, particularly through vertical and horizontal routes.
6. **Subsidize or Provide Free HBV Vaccination for Vulnerable Populations:** The cost of

vaccination remains a barrier, especially for low-income households in rural communities. Government and development partners should **subsidize or provide free vaccination, prioritizing children, healthcare workers, barbers, pregnant women, and those in hotspot LGAs.**

7. **Train and Equip Primary Health Workers in Rural Areas:** Many health workers in rural clinics lack adequate training on HBV diagnosis, counseling, and management. **Capacity-building programs** should be developed to improve their ability to deliver effective HBV services and conduct local awareness outreach.
8. **Strengthen Data Sharing and Collaboration across Stakeholders:** There is a need for improved collaboration between the **Gombe State Ministry of Health, Federal Teaching Hospital, NGOs, and community health platforms** to ensure timely sharing of surveillance data, research findings, and resource mobilization.

By implementing these recommendations, Gombe State can significantly reduce the prevalence and transmission of HBV, particularly among underserved populations, and make measurable progress toward achieving national and global hepatitis elimination targets by 2030.

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