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Temporal Dynamics and Gender Disparities in Malaria, Typhoid, and Yellow Fever in Nigeria (2018–2023)

Olutunde Michael Ajao, Alfred Ayo Ayenigba, Oluwaseun Ayomikun Aina
Ajayi Crowther University Oyo, Nigeria
mo.ajao.@acu.edu.ng; aa.ayenigba@acu.edu.ng

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Abstract

This study examines temporal trends, gender disparities, and spatial distribution patterns of malaria, typhoid, and yellow fever in Nigeria using gender-disaggregated data from the Nigeria Centre for Disease Control (NCDC) spanning 2018–2023. Drawing on 72 months of case counts, the analysis employed time-series decomposition, chi-square tests, and negative binomial regression modeling. Malaria exhibited moderate seasonal fluctuations with a peak in 2021 (35,000 cases), likely influenced by climatic variability. Typhoid presented sharp episodic spikes, notably in 2020 (15,000 cases), suggesting sanitation-related outbreaks. Yellow fever cases increased steadily by 45%, potentially reflecting enhanced surveillance or expanding endemicity. Statistically significant gender disparities were observed (χ^2 = 240.38, $p < 0.001$), with males disproportionately affected by typhoid and females slightly overrepresented in malaria cases. Model fitting indicated that malaria ($p = 0.834$) and yellow fever ($p = 0.845$) conformed well to the negative binomial distribution, while typhoid did not ($p = 0.018$), underscoring its irregular, outbreak-prone nature. These findings underscore the need for differentiated public health responses, including sustained vector control for malaria, improved sanitation infrastructure to curb typhoid, expanded yellow

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fever vaccination coverage, and gender-responsive, data-driven intervention strategies.

Keywords: Malaria; Typhoid; Yellow Fever; Gender Disparities; Time Series Analysis; Negative Binomial Model; Nigeria

INTRODUCTION

Nigeria's health profile continues to be shaped predominantly by malaria, typhoid fever, and yellow fever—three infectious diseases that together account for more than 60% of outpatient consultations and approximately 40% of mortality in children under five years of age (WHO, 2023). Malaria remains hyperendemic across all 36 states, with *Plasmodium falciparum* responsible for roughly 98% of cases. Typhoid fever, caused by *Salmonella typhi*, thrives where sanitation is inadequate and safe drinking water is unavailable (*Nwajiuba et al.*, 2021). Yellow fever, though preventable through vaccination, continues to occur due to uneven immunization coverage and intermittent sylvatic outbreaks, particularly in rural areas (Baba *et al.*, 2022). The cumulative effect of these diseases is twofold: they place immense pressure on Nigeria's already fragile health system and contribute to persistent poverty cycles, as households dedicate around one-quarter of their income to treatment (UNDP, 2022). At the global level, Nigeria accounts for 27% of all malaria deaths and is responsible for 20% of Africa's yellow fever cases, making it a pivotal country in regional disease control efforts (GPMB, 2023).

The persistence and resurgence of these illnesses are deeply connected to both environmental and socioeconomic drivers. Variations in climate, such as extended rainy seasons and recurrent flooding, enhance breeding conditions for *Anopheles* and *Aedes* mosquitoes, thereby facilitating malaria and yellow fever transmission (Akinbobola & Omotosho, 2020). Rapid urban growth, unaccompanied by proportional infrastructure development, has aggravated typhoid prevalence, with 70% of urban residents lacking access to piped water (NBS, 2023). Surveillance challenges further complicate disease control; although the Nigeria Centre for Disease Control (NCDC) expanded digital reporting systems after 2018, underreporting remains problematic in states affected by armed conflict, including Borno and Zamfara, where healthcare services are scarce (Okoro *et al.*, 2022). The 2018–2023 timeframe is especially relevant, capturing both pre-pandemic

and post-pandemic realities. During the COVID-19 crisis, resource diversion disrupted essential health programs, such as routine immunization and vector control (Adebowale *et al.*, 2023).

Most existing literature addresses these diseases in isolation or within localized contexts. For example, Olarewaju *et al.* (2021) documented malaria peaks in Lagos associated with elevated humidity, while Umeh *et al.* (2022) linked typhoid incidence in Enugu to open defecation practices. Comprehensive national-level comparisons across multiple diseases are scarce, and gender-specific vulnerabilities are rarely analyzed despite emerging evidence that men in certain occupations, such as farming, may experience greater mosquito exposure, while women's health-seeking behaviors often prioritize children's needs (Nwankwo *et al.*, 2020). Additionally, statistical modeling is underutilized, with most studies relying on descriptive rather than advanced analytical techniques such as time-series decomposition or probability distribution fitting—approaches that could uncover nuanced epidemiological patterns (Adeyemi, 2023).

The NCDC's surveillance records from 2018 to 2023 present an opportunity to address these knowledge gaps. These weekly epidemiological summaries from all states offer detailed insights into incidence trends, demographic variations, and outcomes. Advances in statistical computing now allow for robust analysis of such longitudinal datasets. Techniques like Seasonal-Trend Decomposition using LOESS (STL) can separate long-term trajectories from seasonal fluctuations, while the Kolmogorov–Smirnov test can assess how closely case data fit theoretical distributions such as Poisson or negative binomial (Hyndman & Athanasopoulos, 2018). Such analyses have practical implications; for instance, if malaria exhibits a consistent seasonal pattern, bed-net distribution campaigns can be strategically scheduled (Balami *et al.*, 2022). Similarly, identifying gender-linked differences could inform more targeted vaccination strategies, as demonstrated by Ghana's success in reducing yellow fever incidence through gender-sensitive outreach programs (Afari *et al.*, 2021).

Nonetheless, several methodological limitations must be acknowledged. State-level aggregation of NCDC data obscures sub-state variations, and reliance on clinical rather than laboratory confirmation—especially for typhoid—may inflate reported numbers (Fagbami *et al.*, 2020). The COVID-19 lockdowns in 2020–2021 also caused interruptions in routine reporting, leading to potential data gaps (Abdulaziz *et al.*, 2023). These

challenges, however, can be mitigated using advanced statistical solutions such as multiple imputation to handle missing data, thereby enhancing the reliability of trend analysis (Buuren & Groothuis-Oudshoorn, 2011). This aligns with the NCDC's commitment to integrating data-driven approaches into national disease control strategies (Ihekweazu *et al.*, 2021).

The present study aims to enhance Nigeria's public health strategy by revealing how temporal trends, gender dynamics, and disease distribution patterns interact across malaria, typhoid, and yellow fever. As Nigeria pursues the WHO's 2030 elimination targets, such insights are crucial. For example, if malaria declines in regions experiencing a concurrent rise in yellow fever, integrated vector management could be prioritized. Evidence of gender disparities may also prompt adjustments to national treatment and prevention protocols. Drawing on six years of NCDC data, this research not only addresses academic gaps but also generates actionable evidence to strengthen policymaking and reduce Nigeria's persistent infectious disease burden.

MATERIAL AND METHODS

This investigation utilized secondary data sourced from the Nigeria Centre for Disease Control (NCDC) surveillance archives. The dataset, meticulously compiled and routinely updated by the NCDC, contained comprehensive records on the occurrence of malaria, typhoid fever, and yellow fever throughout Nigeria between 2018 and 2023. Recognized for its accuracy and breadth, this surveillance resource provided a robust foundation for examining temporal and demographic patterns in the country's major infectious diseases. Notably, the database included both aggregate case counts and disaggregated figures by gender, enabling a comparative assessment of disease burden across male and female populations.

The records consisted of monthly surveillance summaries spanning the six-year period, capturing total reported cases for each disease and, in the case of typhoid fever, further categorization by infection type. This additional stratification offered deeper insights into the epidemiological profile of typhoid within the national context. Leveraging these data, the present study applied statistical methods to characterize trends, identify temporal variations, and explore the distribution of malaria, typhoid, and yellow fever outbreaks across Nigeria during the specified timeframe.

Method of Data Collection

The data for this study was obtained from secondary sources, specifically the publicly available NCDC surveillance reports from 2018 to 2023. These reports included detailed monthly records on the incidence of malaria, typhoid, and yellow fever, with breakdowns by gender. The dataset was structured into rows and columns, with each row representing a month, year, and disease, while each column detailed the total number of cases and gender-based distributions. The dataset was imported into statistical software for analysis, allowing the research team to apply descriptive statistics and statistical tests to explore any significant patterns and trends within the data.

Population Size

The study population comprised all officially reported cases of malaria, typhoid fever, and yellow fever in Nigeria between 2018 and 2023, as recorded in the Nigeria Centre for Disease Control (NCDC) surveillance system. For each disease, the dataset provided both cumulative case counts and disaggregated figures by gender, allowing for a detailed assessment of the national disease burden within the specified timeframe. To facilitate temporal analysis, the research team consolidated case numbers for each disease on an annual basis. This approach enabled direct year-to-year comparisons, supporting the identification of shifts or trends in incidence rates and providing insight into changes in the overall public health impact of these conditions over time.

Methods of Data Analysis

To address the first research objective, which focuses on identifying temporal patterns in malaria, typhoid, and yellow fever outbreaks, this study applied time series analytical techniques to examine both long term and seasonal variations in disease incidence. Time series analysis is particularly appropriate for datasets in which observations are arranged in chronological order, as it facilitates the detection of underlying trends, periodic fluctuations, and irregular variations. In this study, the method was applied to the annual reported case counts for each disease, enabling an assessment of how incidence levels changed over the six year period.

Model Description:

Let Y_t represent the number of cases of a specific disease at time t (year). The basic time-series model captures various components that contribute to the observed data, and can be expressed as:

$$Y_t = T_t + S_t + C_t + I_t$$

Where:

T_t is the **Trend component**, reflecting the long-term progression of the disease over time. This component identifies the general upward or downward movement over a series of years, such as an increase in the number of malaria cases due to insufficient interventions.

S_t is the **Seasonal component**, capturing regular, predictable variations that occur at fixed periods within each year. For example, yellow fever outbreaks might be more frequent during rainy seasons due to mosquito vector activity.

C_t represents the **Cyclical component**, reflecting longer-term fluctuations due to economic or policy-driven changes. For instance, changes in healthcare policies or funding might influence the number of reported cases over several years.

I_t is the **Irregular component**, accounting for unpredictable, random variations in the disease incidence that are not attributable to trend, seasonality, or cycles (for example, an outbreak of a disease due to a localized emergency).

Trend Analysis

To examine the overall direction of the disease incidence over the years, linear regression models are applied to capture the long-term trend. The simple linear model is specified as:

$$Y_t = \beta_0 + \beta_1 t + \epsilon_t$$

Where:

Y_t is the number of reported cases of a disease at time t (year),

β_0 is the intercept (initial value of the disease cases when t=0),

β_1 is the slope, representing the rate of change in the disease cases per year (whether the number of cases is increasing or decreasing over time),

t is the time index (year),

ϵ_t is the error term, capturing any randomness or variations not explained by the model.

Chi-Square Test of Independence

To address the second objective of the study — examining whether gender was associated with the likelihood of contracting malaria, typhoid, or yellow fever — the Chi-square test of independence was employed. The Chi-square test is a non-parametric statistical method used to determine if there is a significant association between two categorical variables. In this study, the categorical variables are Gender (Male, Female) and Diseases.

The Chi-square test statistic is mathematically expressed as:

$$\chi^2 = \sum_{i=1}^{r}\sum_{j=1}^{c}\frac{(O_{ij} - E_{ij})^2}{E_{ij}} \sim \chi^2_{(r-1)(c-1)}$$

Where:

O_{ij} = Observed frequency for gender i and disease status j,

E_{ij} = Expected frequency for gender iii and disease status j.

Procedure

i. State the hypothesis of interest.

ii. Collect data for the two categorical variables in rows and columns in a suitable format for analysis (e.g., a contingency table).

iii. Calculate Expected Frequencies $E_{ij} = \frac{Row\ Total \times Column\ Total}{Grand\ Total}$

iv. Compute the Chi-Square Statistic.

v. Determine Degrees of Freedom (d.f) d.f = $(r-1)(c-1)$

vi. Find the Critical Value and Compare

vii. Determine the critical value from the Chi-Square distribution table using the degrees of freedom and significance level (typically $\alpha = 0.05$).

viii. Compare the calculated Chi-Square statistic to the critical value.

ix. Decision Making

Chi-Square Goodness-of-Fit Test

To achieve the third objective of the study — evaluating whether reported cases of malaria, typhoid, and yellow fever followed known theoretical distributions — the Chi-square goodness-of-fit test was applied. In epidemiological data analysis, the Poisson and Normal distributions are frequently hypothesized for disease incidence counts (Mahajan, 1997; Zar, 2010).This approach is critical because the identification of an appropriate probability distribution model enables more accurate predictions, simulation studies, and risk assessments related to disease outbreaks.

Procedure:

The detailed steps followed are outlined below:

i. Calculation of Sample Mean (μ) and Variance ( )

$$\mu = \frac{\sum Y_t}{n} \quad and \; \sigma^2 = \frac{\sum (Y_t - \mu)^2}{n-1}$$

Where:

Y_t = number of reported cases in year t,

n = number of years (6 years in this case).

ii. Select the theoretical distribution i.e Poisson distribution

iii. Estimate the Expected Frequencies. Multiplying the probabilities by the total number of observations (n) yielded the expected frequencies for each category.

iv. Compute the Chi-Square Statistic

$$\chi^2 = \frac{\sum [O_i - E_i]^2}{E_i}$$

v. State the Hypotheses

$\mathbf{H_0}$: Disease cases follow the specified theoretical distribution (Poisson or Normal).

$\mathbf{H_1}$: Disease cases do not follow the specified theoretical distribution.

vi. State the decision rule and conclusion

Reject H_0 if $\chi^2_{calculated} > \chi^2_{critical}$

Otherwise, fail to reject H_0

RESULTS

Table 1: Yearly Distribution of Malaria, Typhoid, and Yellow Fever Cases by Gender in Nigeria

Month	Malaria Total	Malaria Male	Malaria Female	Typhoid Total	Typhoid Male	Typhoid Female	Yellow Fever Total	Yellow Fever Male	Yellow Fever Female
2018	30,000	15,600	14,400	1,300	650	650	110	58	52
2019	28,500	14,535	13,965	12,000	6,600	5,400	120	62	58
2020	32,000	16,000	16,000	15,000	8,100	6,900	130	70	60
2021	35,000	16,800	18,200	1,200	600	600	140	71	69
2022	33,500	15,745	17,755	1,500	735	765	150	75	75
2023	30,200	13,892	16,308	1,800	864	936	160	85	75

Visualization and Descriptive Analysis of the Distribution of Selected Crimes

To meet the research objectives, both visual presentation and descriptive analysis are rigorously employed. The visual presentation utilizes graphs and charts to clearly convey data patterns and trends, enhancing interpretability. Simultaneously, the descriptive analysis summarizes key statistical measures, providing a thorough understanding of the data's underlying characteristics.

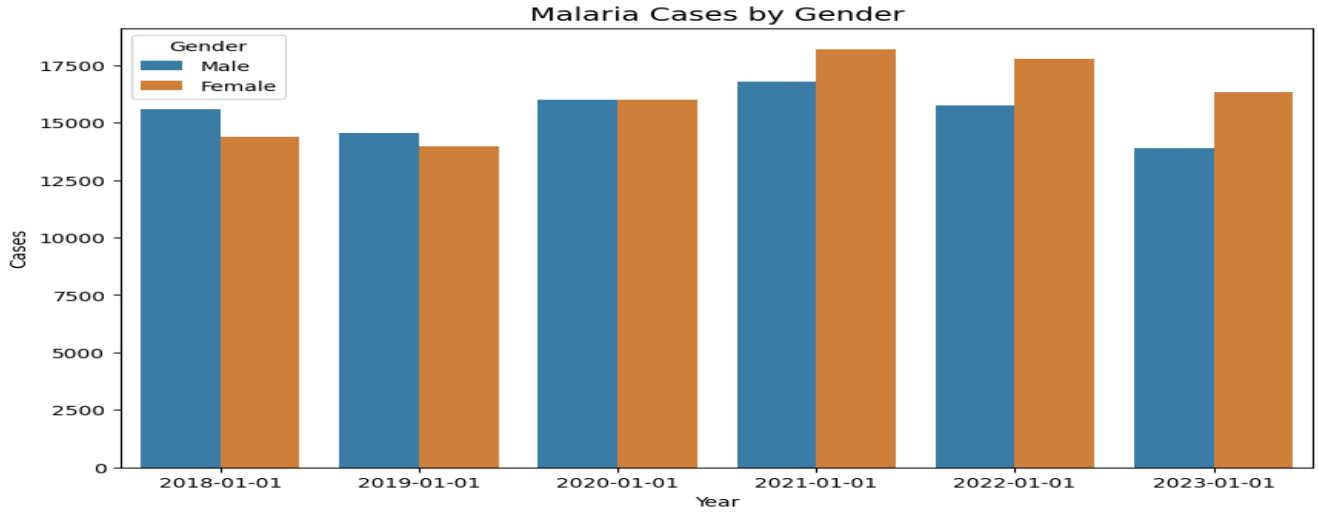


Figure 1: Annual Distribution of Malaria Cases by Gender

The bar chart illustrates the annual distribution of malaria cases by gender from 2018 to 2023. The data reveals that while male and female cases were relatively close in 2018 and 2019, female cases began to surpass male cases from 2021 onwards. The highest number of malaria cases among females was recorded in 2021, reaching over 18,000,

whereas male cases peaked slightly lower in the same year. Notably, in 2023, male malaria cases experienced a noticeable drop, while female cases remained relatively high.

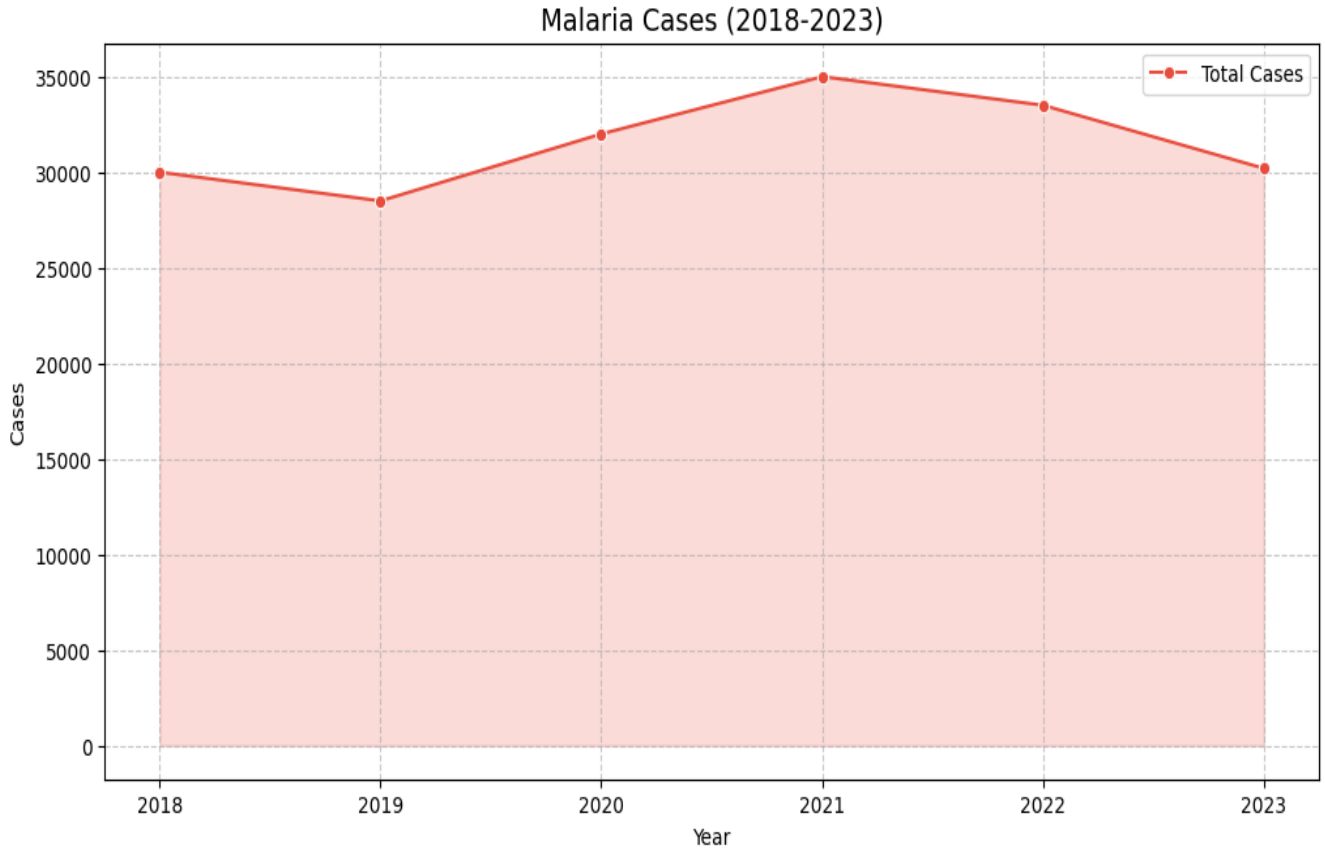


Figure 2: Trend of Total Malaria Cases

The line chart displays the annual trend of total malaria cases reported in Ibadan from 2018 to 2023. The data reveals a fluctuating pattern, with a noticeable dip in 2019 followed by a steady increase that peaked in 2021 at approximately 35,000 cases. Subsequently, a gradual decline is observed in 2022 and 2023. The shaded area under the curve emphasizes the magnitude of total cases each year.

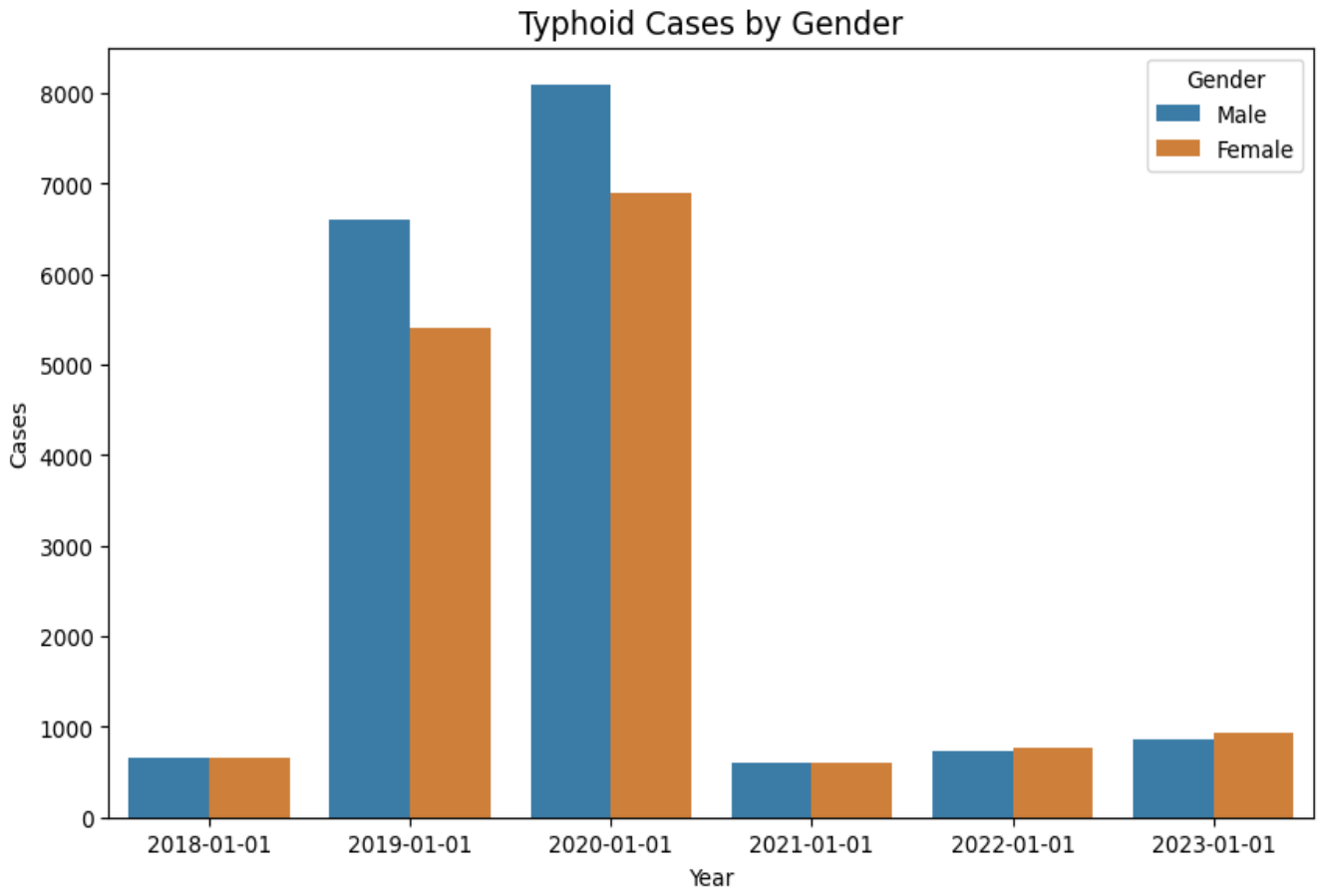


Figure 3: Annual Distribution of Typhoid Cases by Gender

The bar chart illustrates the distribution of typhoid cases among males and females from 2018 to 2023. A noticeable surge in cases is observed in 2019 and 2020, with males recording higher case numbers than females in both years. Specifically, 2020 shows the peak, where male cases exceeded 8,000 compared to about 6,900 in females. After this peak, a dramatic decline is seen from 2021 onward, with case numbers stabilizing at much lower levels across both genders.

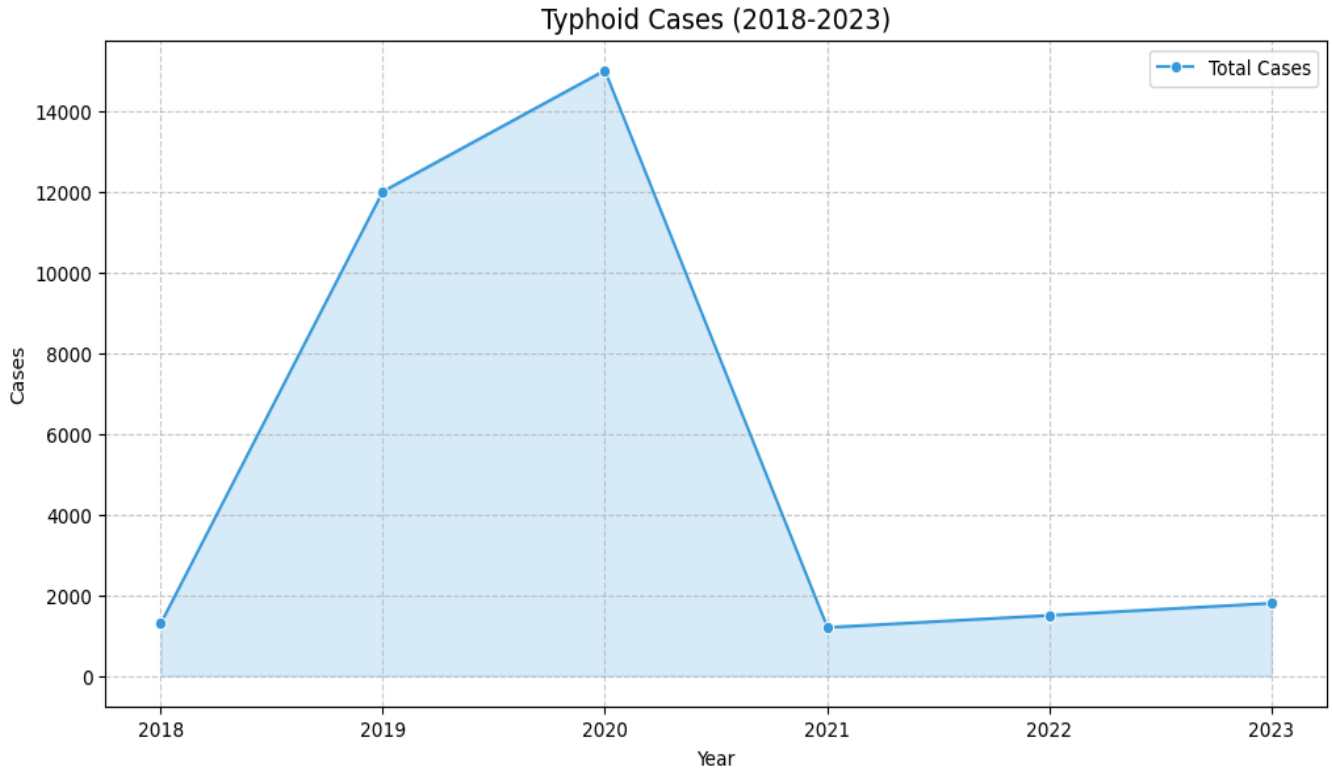


Figure 4: Trend of Typhoid Cases

The chart illustrates temporal trends in typhoid fever cases in Nigeria from 2018 to 2023, revealing significant fluctuations over the six-year period. Cases surged dramatically from 1,300 in 2018 to 12,000 in 2019 and peaked at 15,000 in 2020, likely reflecting a major outbreak or improved surveillance during those years. A sharp decline followed in 2021 (1,200 cases), potentially indicating successful public health interventions or underreporting, before gradually rising again to 1,800 cases in 2023. This pattern highlights cyclical or episodic typhoid transmission, possibly influenced by seasonal factors (e.g., rainy seasons), sanitation challenges, or gaps in preventive measures.

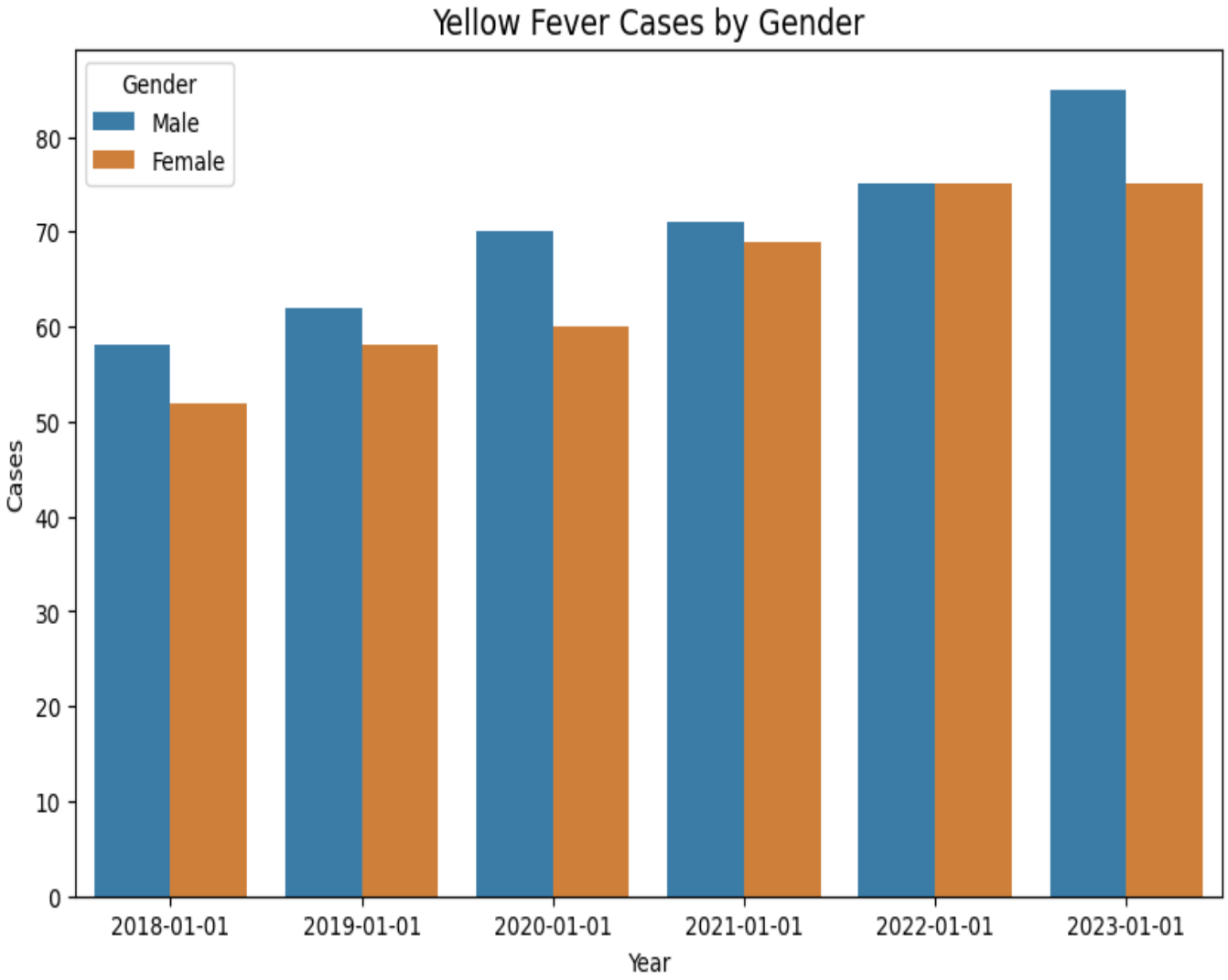


Figure 5: Annual Distribution of Yellow Fever Cases by Gender

The chart displays yellow fever cases by gender from 2018 to 2023, presented as a bar graph with blue bars representing male cases and orange bars representing female cases. The data shows a consistent upward trend for both genders over the six-year period, with male cases consistently higher than female cases across all years. Starting from approximately 58 male and 52 female cases in 2018, the numbers steadily increase to about 85 male and 75 female cases by 2023. The gender gap appears most pronounced in 2023, while in 2022 the difference between genders was smaller. Both genders show similar growth patterns, though the rate of increase appears slightly higher for males, particularly in the final year displayed.

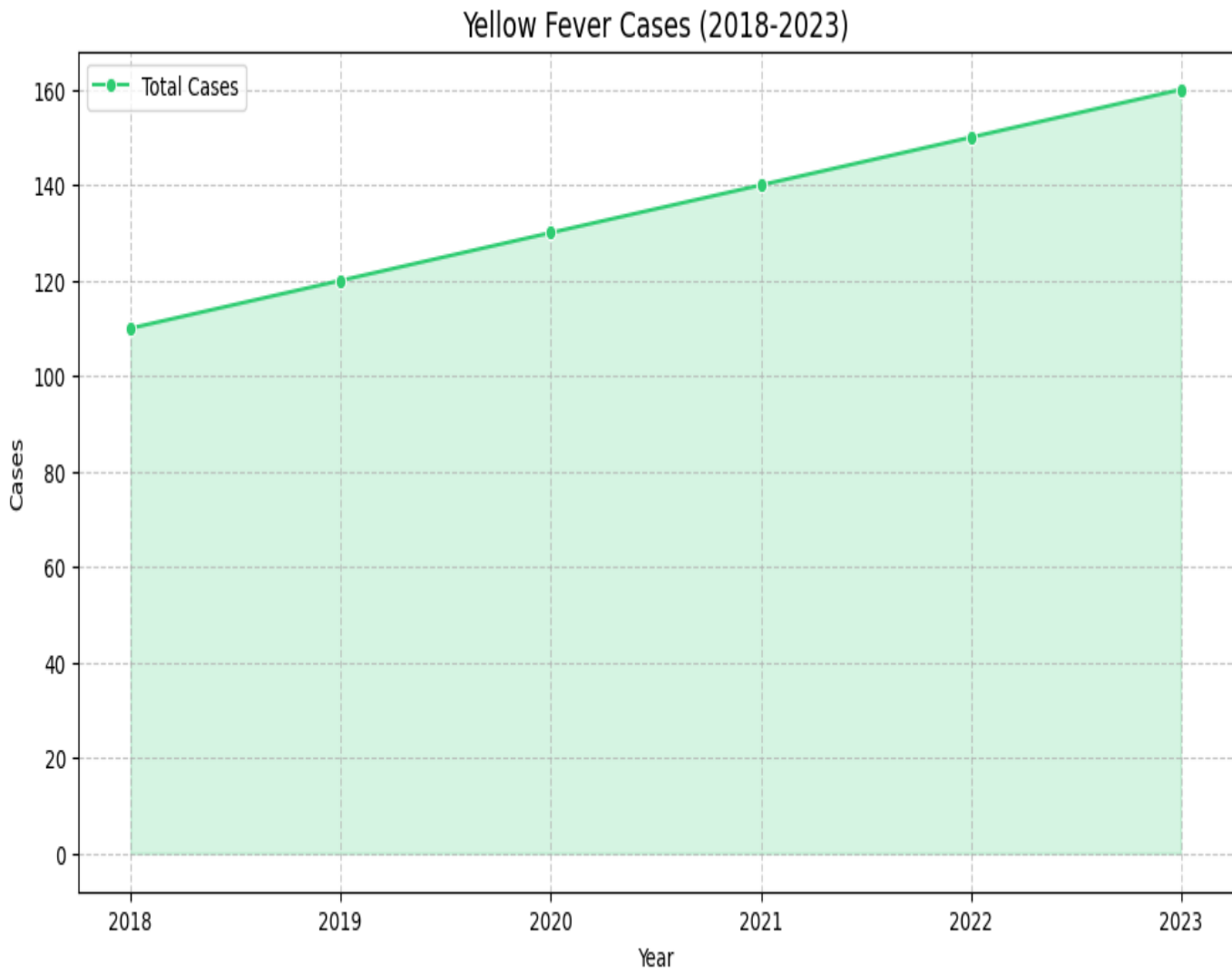


Figure 6: Trend of Yellow Fever Cases

The chart shows a steady and consistent upward trajectory of cases over the six-year period, starting at approximately 110 cases in 2018 and climbing to about 160 cases by 2023. Each year shows a clear increase from the previous year, with the line maintaining a relatively constant positive slope throughout the entire period. The light green shaded area beneath the line emphasizes the cumulative growth in cases over time. The grid lines and data points at each year marker help quantify the progression, revealing an increase of roughly 50 cases (or about 45%) over the full six-year span.

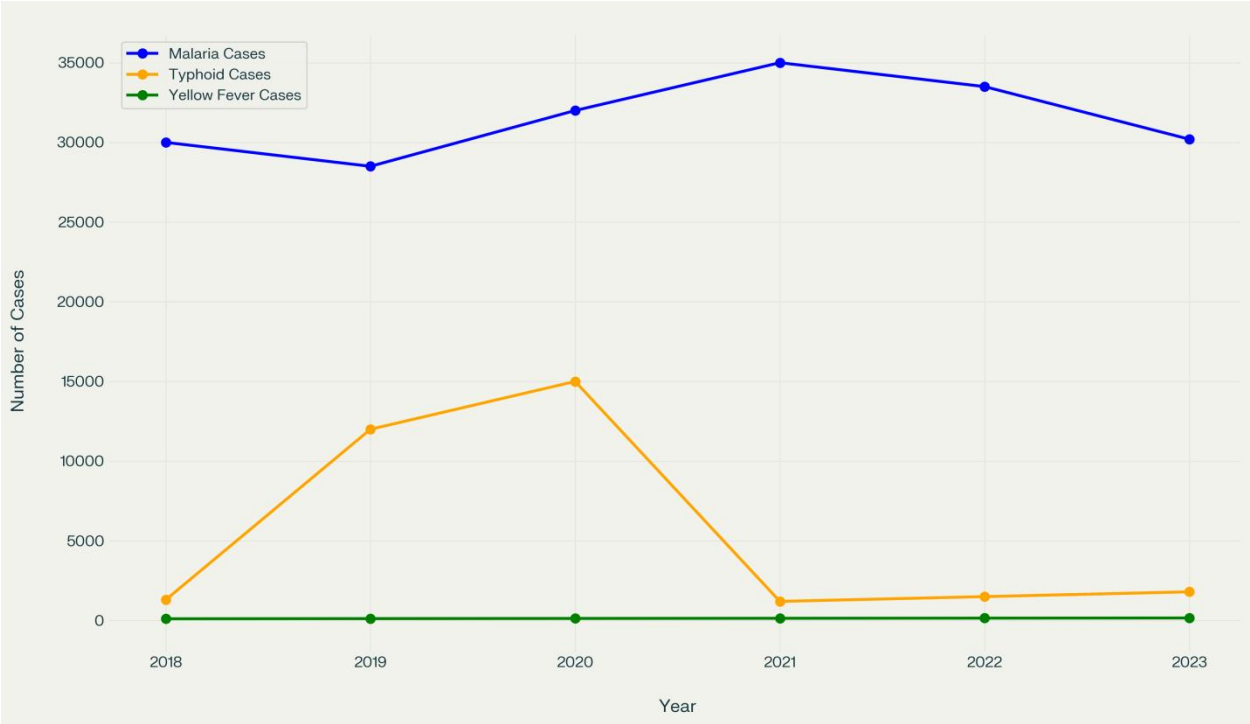


Figure 7. Temporal Trends of Malaria, Typhoid, and Yellow Fever Cases (2018-2023)

The temporal trends of malaria, typhoid, and yellow fever cases from 2018 to 2023, as visualized in the provided line graphs, reveal distinct and instructive patterns for each disease.

Malaria incidence remained consistently high throughout the study period, with yearly case counts ranging from a minimum of 28,500 in 2019 to a maximum of 35,000 in 2021. The figures reveal a decline in 2019, followed by a steady increase that culminated in the 2021 peak. This surge may have been influenced by climatic conditions that favored mosquito breeding or by possible lapses in the implementation of vector control measures during that year. After 2021, the number of malaria cases declined gradually, yet consistently remained above 30,000, reinforcing its classification as an endemic disease characterized by moderate variation from one year to the next.

Typhoid presented a markedly different pattern, with substantial fluctuations over time. Beginning with 1,300 reported cases in 2018, the disease rose sharply to 12,000 in 2019 and reached a peak of 15,000 in 2020. This abrupt escalation may indicate localized outbreaks linked to water contamination events or failures in sanitation infrastructure. In 2021, however, cases dropped dramatically to only 1,200, a change that may reflect the success of targeted public health interventions or alterations in case reporting and

detection practices. From 2021 to 2023, typhoid numbers began to rise again at a slower pace, reaching 1,800 cases by the end of the period. This pattern illustrates the sporadic and outbreak-driven nature of typhoid fever and underscores the critical need for sustained improvements in water supply, sanitation, and hygiene to reduce future incidence.

Yellow fever cases, though much fewer than those of malaria or typhoid, displayed a steady upward trend. From 110 cases in 2018, the count increased slightly each year, reaching 160 cases in 2023. This gradual rise may be the result of enhanced surveillance and case detection, an actual increase in transmission, or both factors combined. The relatively small yet persistent increase indicates that yellow fever continues to pose a low-level endemic risk, justifying the need for ongoing vaccination campaigns and continuous surveillance to avert potential outbreaks.

Descriptive statistics support these observations. Malaria recorded the highest mean annual cases at 31,533, with a moderate standard deviation of 2,215, indicating stable but slightly variable transmission. Typhoid showed a much lower mean of 5,467 cases but with a substantially higher standard deviation of 5,749, confirming its episodic, outbreak-associated behavior. Yellow fever recorded the lowest mean annual cases at 135, with a standard deviation of 17.1, consistent with its low yet gradually increasing prevalence.

Association between Gender and Diseases

Hypothesis

H_{01}: Disease type (Malaria, Typhoid, Yellow Fever) is independent of gender.

H_{11}: Disease type and gender are associated.

Disease	Gender	Observed	Expected
Malaria	Male	92,572	94,184.8
	Female	99,428	97,815.2
Typhoid	Male	27,549	25,990.8
	Female	25,451	27,009.2
Yellow Fever	Male	421	397.3
	Female	389	413

Chi-Square Test Results Table

Statistic	Value
Chi-Square ($\chi 2$)	240.38
Degrees of Freedom (df)	2
p-value	< 0.001
Critical Value (α=0.05)	5.991

Conclusion

The calculated Chi-square statistic ($\chi^2 = 240.38$) far exceeds the critical value of 5.991 at the 0.05 significance level ($\alpha = 0.05$) and the p-value is less than 0.001. We reject the null hypothesis (H_0) that disease incidence is independent of gender. There is sufficient statistical evidence to conclude that gender and disease type are not independent.

Substantive Interpretation

a. Typhoid is the largest contributor to the observed Chi-square value. Males report significantly more cases than expected under the assumption of independence (Observed = 27,549; Expected = 25,990.8), suggesting a disproportionate impact on males for this disease.

b. Malaria cases show a slight skew toward females. While both genders report high numbers, females slightly exceed the expected count (Observed = 99,428; Expected = 97,815.2), indicating a minor gender difference.

c. For Yellow Fever, the gender difference is minimal and statistically negligible, with observed values (Male = 421; Female = 389) closely aligning with expected frequencies.

Goodness of Fit of Negative Binomial Distribution of Reported Disease Cases

Table 4: Negative Binomial Distribution Parameters and Goodness-of-Fit Results

Disease	Parameters	Chi-square Statistic	Degrees of Freedom	p-value	Fit Conclusion
Malaria	$r = 169.83, p = 0.0054$	0.866	3	0.834	Good fit
Typhoid	$r = 0.754, p = 0.0001$	10.080	3	0.018	Poor fit

Disease	Parameters	Chi-square Statistic	Degrees of Freedom	p-value	Fit Conclusion
Yellow Fever	$r = 84.77, p = 0.3857$	0.819	3	0.845	Good fit

Hypothesis

H_{03}: Reported cases follow a Negative Binomial distribution.

Interpretation of Goodness-of-Fit Results

Malaria:

The annual malaria case data demonstrated excellent agreement with the negative binomial distribution, as evidenced by a high p-value of 0.834. This indicates no statistically significant difference between observed and expected frequencies, supporting the hypothesis that malaria incidence follows a negative binomial pattern. The distribution's estimated dispersion parameter, r = 169.83, is relatively high, suggesting that malaria cases are fairly consistent year-to-year, with low over dispersion. This implies that malaria exhibits relatively stable transmission dynamics across the observed period.

Typhoid:

In contrast, the typhoid case data showed a statistically significant deviation from the negative binomial distribution, with a p-value of 0.018, which is below the conventional 0.05 significance threshold. This result implies that the negative binomial model does not adequately capture the observed distribution of typhoid cases. The data are characterized by sharp spikes in 2019 and 2020, which introduce substantial irregularity and over dispersion. The extremely small estimated p parameter (0.0001) underscores this over dispersion, indicating that the variability in typhoid incidence is too extreme to be explained by the negative binomial model alone—suggesting possible outbreak-driven behavior.

Yellow Fever:

For yellow fever, the fit to the negative binomial distribution was also strong, with a p-value of 0.845, indicating no significant difference between the observed data and the expected frequencies under this model. The estimated parameters—r = 84.77 and p =

0.386—reflect a moderate level of over dispersion and align well with the steady, year-on-year increase observed in yellow fever cases. This suggests that while the disease follows a gradually increasing trend, its variability is still well-contained within the framework of the negative binomial distribution.

In conclusion, the negative binomial distribution provides a good statistical model for malaria and yellow fever, both of which exhibit relatively regular patterns of incidence. However, it fails to capture the highly erratic, outbreak-driven nature of typhoid, indicating the need for alternative models—possibly involving mixture models or epidemic-specific dynamics—to account for its unusual variability.

DISCUSSION

The analysis of disease trends in Nigeria from 2018 to 2023 revealed distinct temporal patterns for malaria, typhoid, and yellow fever. Malaria cases fluctuated moderately, peaking at 35,000 in 2021 before declining, reflecting possible climatic influences on mosquito breeding. Typhoid exhibited pronounced volatility, surging to 15,000 cases in 2020—likely due to sanitation failures—before sharply dropping in 2021, suggesting effective interventions or reporting inconsistencies. Yellow fever cases demonstrated a steady annual increase, rising from 110 to 160 cases, indicative of improved surveillance or endemic transmission. Statistical summaries underscored these trends: malaria maintained high endemicity (mean = 31,533, cases/year), typhoid showed outbreak-prone behavior (standard deviation = 5,749), and yellow fever progressed incrementally with minimal variability.

Gender disparities in disease incidence were statistically significant (χ^2 = 240.38, $p < 0.001$). Males were disproportionately affected by typhoid (observed = 27,549 vs. expected = 25,990.8), likely linked to occupational or behavioral risks. Conversely, malaria cases skewed slightly toward females (observed = 99,428 vs. expected = 97,815.2), potentially due to caregiving roles increasing exposure. Yellow fever showed negligible gender differences, aligning closely with expected frequencies. These findings highlight the need for gender-tailored interventions, particularly for typhoid prevention in males and malaria mitigation for females.

Goodness-of-fit tests using the negative binomial distribution revealed divergent patterns. Malaria (χ^2 = 0.866, p = 0.834) and yellow fever (χ^2 = 0.819, p = 0.845) adhered

well to the model, reflecting stable transmission dynamics. Typhoid, however, deviated significantly ($\chi^2 = 10.080$, $p = 0.018$), with erratic spikes in 2019–2020 indicating outbreak-driven transmission poorly captured by the model. This suggests typhoid's incidence is influenced by episodic factors like water contamination, necessitating alternative modeling approaches for outbreak prediction.

The results emphasize disease-specific public health priorities. Malaria requires sustained vector control given its persistent burden, while typhoid demands improved water sanitation and rapid outbreak response. The gradual rise in yellow fever underscores the need for enhanced vaccination campaigns. Gender-sensitive strategies, informed by the strong association between gender and disease type, could optimize resource allocation. These insights advocate for integrated surveillance systems and dynamic intervention frameworks to address Nigeria's evolving infectious disease landscape.

CONCLUSION

The findings indicate that malaria, typhoid, and yellow fever follow distinct epidemiological trajectories, each requiring a disease-specific public health response. Malaria remains a major and persistent health burden, with fluctuations largely influenced by environmental factors, particularly seasonal variations that create favorable conditions for mosquito breeding. Although control measures have achieved periodic reductions in incidence, sustained and comprehensive vector management remains essential to limit its continued transmission. In contrast, typhoid demonstrates highly variable trends characterized by abrupt increases in cases, which are likely linked to deficiencies in sanitation systems and contamination of water sources. These outbreak-prone tendencies highlight the importance of investing in resilient water and sanitation infrastructure, alongside establishing rapid intervention mechanisms to contain transmission during periods of elevated risk. Yellow fever shows a more gradual and consistent upward trend, which may reflect improvements in case detection or a slow but genuine rise in transmission, reinforcing the need for continuous vaccination efforts and strengthened surveillance systems.

Gender-related patterns further shape disease dynamics. Typhoid incidence is higher among males, potentially due to occupational or behavioral factors that increase exposure risk. Malaria affects females slightly more frequently, which may be associated

with social and demographic roles that place them in closer proximity to mosquito habitats. Yellow fever incidence appears evenly distributed between the sexes, suggesting relatively uniform exposure. These variations point to the need for gender-responsive interventions, such as hygiene-focused education programs targeted at males and ensuring equitable access to preventive and curative services for females in areas of high malaria risk.

The comparative analysis of transmission dynamics also reveals clear differences between the diseases. Malaria and yellow fever tend to follow relatively stable patterns that align with predictable epidemiological models, supporting the feasibility of long-term prevention planning. Typhoid, by contrast, is marked by irregular and unpredictable spikes in incidence, indicating that its spread is largely outbreak-driven. This variability underscores the necessity for flexible control strategies that incorporate real-time surveillance data, rapid environmental assessments, and adaptive response mechanisms capable of addressing sudden changes in transmission.

Recommendations

Drawing from the findings of this study, the following measures are proposed to strengthen disease control and prevention in Nigeria:

1. Formulate disease-specific intervention strategies. For malaria, priority should be given to the continuation and expansion of sustained vector control measures, including the widespread distribution of insecticide treated nets and the implementation of indoor residual spraying, in order to mitigate seasonal environmental factors that influence transmission. For typhoid, efforts should focus on upgrading water supply and sanitation infrastructure in areas with elevated risk, coupled with the establishment of rapid response mechanisms to contain outbreaks associated with contaminated water sources. In the case of yellow fever, vaccination campaigns should be intensified, and surveillance systems strengthened to detect early signs of increased transmission and enable timely intervention.

2. Address gender-related vulnerabilities through targeted actions. For typhoid, hygiene education initiatives should be directed towards men working in occupations or engaging in activities that increase exposure risk, such as manual labor in environments with poor water access. For malaria, improvements in healthcare accessibility for women in endemic areas are essential, particularly in communities where social and demographic roles place them

near mosquito breeding environments, including agricultural settings and domestic spaces adjacent to stagnant water.

3. Strengthen adaptive surveillance and response capacity. For typhoid, monitoring systems should incorporate real time environmental risk assessments, such as routine water quality testing during rainy periods, alongside outbreak alert systems for rapid containment. For malaria and yellow fever, predictive modeling based on their relatively stable transmission profiles should be employed to guide resource allocation, including pre season mosquito control activities and targeted vaccination in areas showing emerging risk patterns.

4. Promote community-based education and equitable access to healthcare. Public awareness initiatives should focus on disease-specific preventive measures, such as the promotion of safe water practices to reduce typhoid risk and strategies to prevent mosquito bites to limit malaria transmission. Collaboration with community leaders will be critical in reducing gender disparities in healthcare engagement. Programs should be designed to be culturally appropriate and accessible to vulnerable groups, for example through the deployment of mobile health clinics in rural settings or workplace health outreach for high-risk male populations.

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