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Typhoid Incidence and Infant Mortality across Nigerian Regions, 2015–2024: Descriptive Trends and Association Tests

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study examines regional disparities in typhoid fever incidence and infant mortality across Nigeria from 2015 to 2024.Retrospective ecological study. Nigeria, covering the period 2015–2024. Secondary data were obtained from annual reports of the Nigeria Centre for Disease Control (NCDC) and the National Population Commission (NPC). Nigeria's six geopolitical zones were aggregated into five macro-regions (Central, North, East, South, and West). Typhoid incidence was measured as cases per 100,000 population, while infant mortality was expressed as deaths per 1,000 live births. Descriptive statistics, Spearman correlation, fixed-effects panel regression, and one-way ANOVA were employed. The West region recorded the highest average typhoid incidence and infant mortality over the study period. Strong positive correlations between typhoid incidence and infant mortality were observed in the West ($\rho = 0.89$, $p < 0.001$) and South ($\rho = 0.82$, $p = 0.023$). One-way ANOVA confirmed significant regional differences ($F = 8.64$, $p = 0.002$), with post hoc analysis indicating that disparities were primarily driven by the West region. Substantial regional inequities persist in typhoid burden and infant mortality in Nigeria. Targeted, region-specific interventions focusing on water, sanitation, vaccination, and maternal–child health services are essential for reducing preventable infant deaths.

Keywords: *Typhoid; fever; Regional disparities; Infant Mortality; Nigeria*

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1.INTRODUCTION

In contemporary infectious disease epidemiology, *Salmonella enterica* serovar Typhi continues to exemplify the nexus between poverty, inadequate sanitation, and preventable mortality. In sub-Saharan Africa, particularly Nigeria, typhoid fever remains a persistent public health threat rather than a historical remnant. Although global incidence has declined since 1990, the burden in low- and middle-income countries remains substantial, with enduring effects on child survival and development (Liu *et al*., 2025; Ahmed *et al*., 2025). Given Nigeria's persistently high infant mortality rates, the coexistence of endemic typhoid transmission and elevated childhood deaths constitutes a critical epidemiological priority requiring rigorous empirical assessment.

Nigeria is classified as hyperendemic for typhoid fever, with approximately 100 cases per 100,000 population, yet subnational variation and its linkage with infant mortality remain insufficiently quantified (Kim *et al*., 2023). Profound regional disparities in child survival persist, with neonatal mortality ranging from 31 to 39 per 1,000 live births and under-five mortality varying from 187 per 1,000 in the North West to 56 per 1,000 in the South East (Somorija *et al*., 2025). The contribution of typhoid to these outcomes is unclear, particularly in contexts where clinical overlap with malaria obscures accurate diagnosis and delays treatment (Lawal *et al*., 2025). Although the Severe Typhoid in Africa programme has generated incidence estimates for Nigeria, comprehensive analyses integrating subnational typhoid trends with infant mortality between 2015 and 2024 are lacking (Marks *et al*., 2024), limiting evidence-based vaccine and WASH policy decisions.

Recent evidence has refined understanding of enteric fever dynamics. Global analyses report a 62% decline in incidence from 1990 to 2021, yet mortality reductions have been modest and antimicrobial resistance increasingly complicates management (Liu *et al*., 2025; Ahmed *et al*., 2025). In sub-Saharan Africa, children under five experience disproportionate morbidity, with hospital case fatality rates often exceeding 5% (Adesegun *et al*., 2020). Nigerian studies identify environmental determinants such as temperature, humidity, population density, and contaminated water proximity as significant predictors of transmission (Umar *et al*., 2024). Meanwhile, research on infant mortality highlights multilevel determinants but seldom models typhoid as an independent risk factor while adjusting for confounders (Nwanze *et al*., 2023; Haganawiga *et al*., 2025). Thus, the intersection between regional typhoid burden and infant survival remains underexplored.

This study addresses this gap by examining temporal and spatial concordance between typhoid incidence and infant mortality across Nigeria's six geopolitical zones over a decade. Using descriptive epidemiology and multivariable association testing, it situates enteric infection within the broader determinants of child survival. Comparative analysis of regional trends identifies areas of convergent burden, informing targeted intervention priorities. The findings strengthen Nigeria's epidemiological evidence base and support policy decisions regarding typhoid conjugate vaccine introduction and WASH investment, consistent with global guidance (Radhakrishnan *et al*., 2018). Quantifying the association between typhoid incidence and infant mortality enables estimation of the potential attributable contribution of enteric fever to infant deaths in a resource-constrained setting.

2. METHOD

2.1 Study Design and Data Sources

This study employed a retrospective ecological design using secondary data obtained from the Nigeria Centre for Disease Control (NCDC) and the National Population Commission (NPC) for the period 2015–2024.

2.2 Regional Classification

For analytical clarity, Nigeria's six geopolitical zones were aggregated into five macro-regions: Central (North Central), North (North East and North West), East (South East), South (South South), and West (South West).

2.3 Variables and Measurement

Typhoid fever incidence was measured as reported cases per 100,000 population. Infant mortality was measured as deaths per 1,000 live births. All infant mortality values were rescaled to ensure consistency with standard demographic definitions.

2.4 Sample Size and Missing Data

The dataset comprised up to 50 region-year observations (5 regions × 10 years). Data for the South region were unavailable for selected years (2021–2023); analyses were therefore conducted using available-case observations.

2.5 Statistical Analysis

Descriptive statistics were used to summarize trends and regional distributions. Spearman's rank correlation coefficient assessed associations between typhoid incidence and infant mortality. Fixed-effects panel regression accounted for unobserved regional heterogeneity. One-way ANOVA tested for regional differences, followed by Tukey's HSD post hoc analysis. Statistical significance was assessed at the 5% level.

2.6 Methods of Data Analysis

2.6.1 Correlation Analysis

To evaluate the monotonic relationship between typhoid fever incidence and infant mortality rates across Nigerian regions, this study employs Spearman's rank correlation coefficient (ρ). This non-parametric method is particularly suitable when the data do not meet the assumptions of linearity or normality required by Pearson's correlation. Given the potential for non-linear and non-normally distributed epidemiological data across regions and time periods, Spearman's ρ provides a robust alternative for assessing the strength and direction of association between two ranked variables.

The Spearman correlation coefficient is defined mathematically as:

$$\rho = 1 - \frac{6\sum d^2{}_i}{n(n^2-1)} \quad \text{.....(1)}$$

Where:

ρ is Spearman's rank correlation coefficient,

$d_i$is the difference between the ranks of paired observations (i.e., typhoid incidence and infant mortality) for the ithobservation,n is the number of paired observations.

1. Significance Testing: To test for statistical significance, a two-tailed test was conducted using the t-distribution with degrees of freedom $df = n - 2$, calculated as:

$$t = \frac{\rho\sqrt{n-2}}{\sqrt{1-\rho^2}} \quad \text{.....(2)}$$

2. Interpretation: The resulting p-value was compared against a standard significance level (α = 0.05) to determine whether a statistically significant correlation exists between typhoid incidence and infant mortality.

2.6.2 One-Way ANOVA for Regional Comparison

This study applies one-way analysis of variance to examine regional differences in typhoid fever incidence and infant mortality rates across Nigeria's five geopolitical zones, namely Central, East, North, South, and West, over the period 2015 to 2024. The approach enables systematic comparison of mean outcomes across regions and facilitates identification of statistically significant spatial disparities over the ten-year timeframe.

2.6.3 Model Specification

Let Y_{ij} represent the dependent variable (either typhoid incidence per 100,000 or infant mortality rate per 1,000 live births) observed in the jth year for the ith region. The model is specified as:

$$Y_{ij} = \mu + \tau_i + \epsilon_{ij} \quad \text{.....(3)}$$

Where:

μ is the overall mean of the dependent variable,

τ_i is the effect of the ithregion (i = 1,2, 3, 4, 5),

ϵ_{ij} is the random error term, assumed to be normally distributed with mean 0 and constant variance σ^2,
$\sum \tau_i = 0$, ensuring model identifiability.

2.6.4Hypotheses
For each dependent variable, the hypotheses tested are:
H_0: *There is no significant difference in the mean rates across the regions.*
H_1:At least one region has a mean significantly different from the others.

3. RESULT AND DISCUSSION

3.1 Results

The methodology combines descriptive statistics to summarize and visualize temporal patterns in typhoid incidence and infant mortality with inferential techniques to test the study hypotheses. Correlation and regression analyses assess the relationship between typhoid burden and infant mortality, while one-way analysis of variance evaluates regional differences in mean values. Results are presented using structured tables, graphical illustrations, and concise narrative interpretation to support evidence-based conclusions.

Table 1: *Annual Typhoid Incidence and Infant Mortality Rates by Region in Nigeria*

YEAR	Region	Total Typhoid Cases (per 100,000)	Total Infant Mortality Rate (per 1,000 live births)
2024	Central	29	6.44
	East	252	8.72
	North	141	3.37
	South	5	2,28
	West	389	50.45
2023	East	120	23.61
	North	70	9.48
	West	82	16.72
2022	Central	159	18.92
	East	99	8.80
	North	85	13.70
	West	119	8.16
2021	Central	146	14.90
	East	87	8.92
	North	97	10.95
	West	287	28.03
2020	Central	171	17.84
	East	125	21.93
	North	308	9.72
	South	126	15.72
	West	125	18.42
2019	Central	138	22.86
	East	15	9.13
	North	50	10.79
	South	206	12.60
	West	349	44.17
2018	Central	231	24.26
	East	205	26.14
	South	283	48.75
	West	66	5.16
2017	Central	172	10.49
	East	46	19.76
	North	279	38.72
	South	94	10.38

	West	32	5.84
2016	Central	228	24.08
	East	100	20.27
	North	77	7.71
	South	123	15.97
	West	31	7.28
2015	Central	216	19.82
	East	97	7.46
	North	280	27.46
	South	49	11.52
	West	181	13.82

Table 2: *Total Typhoid Cases and Infant Mortality Rates by Region*

Region	**Cumulative Typhoid incidence**	**Mean Infant Mortalityper 1,000**
Central	1,918	17.97
East	1,146	15.48
North	1,397	12.99
South	886	11.72
West	1,641	19.81

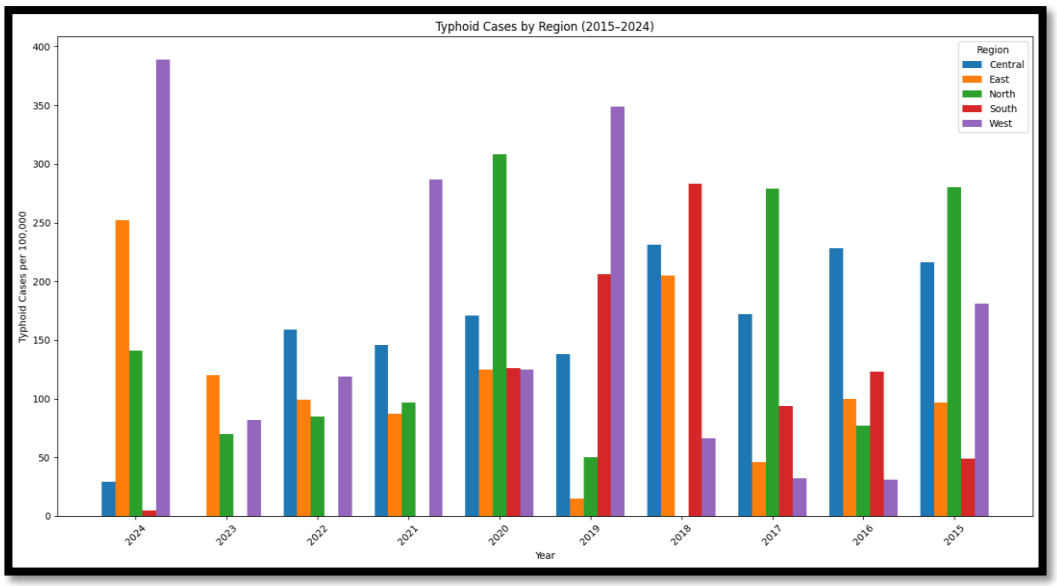

Figure 1. *Bar Representation of Typhoid Cases by Region*

Figure 1 demonstrates pronounced regional and temporal heterogeneity in typhoid burden across the study period. The West recorded the highest incidence in 2024, approaching 400 cases per 100,000 population, with another marked elevation in 2019 at approximately 350 per 100,000. The North maintained persistently high rates between 2015 and 2020, consistently exceeding 250 per 100,000. The South reached its peak in 2018 at roughly 280 per 100,000. In contrast, the Central region exhibited comparatively moderate levels overall, though with a noticeable upward trajectory from 2018 to 2024. The East experienced its greatest burden in 2024 at about 250 per 100,000, followed by a general decline in subsequent years.

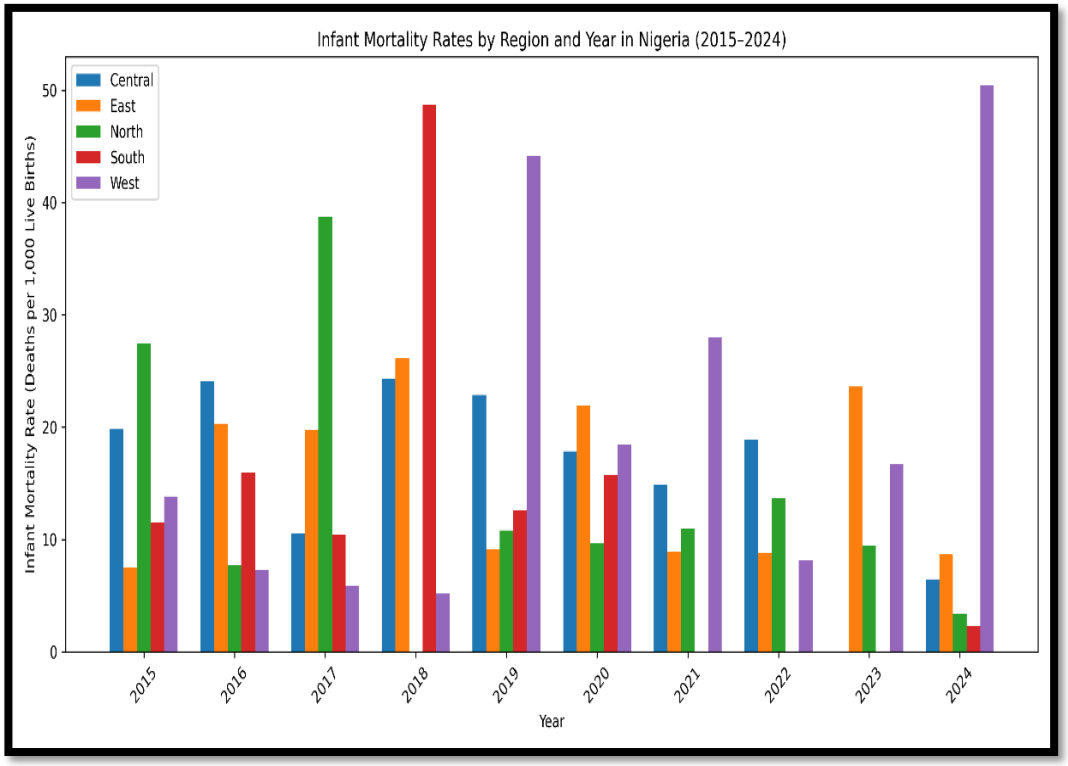

Figure 2. *Bar Representation of Infant Mortality Rates Cases by Region*

The grouped bar chart of infant mortality rates per 1,000 live births from 2015 to 2024 indicates persistent regional disparities and marked annual fluctuations, with no consistent evidence of nationwide decline. The West repeatedly recorded elevated levels, peaking at approximately 50 in 2024 and remaining among the poorest-performing regions throughout the period. The North exhibited the highest single observation in the dataset at about 39 in 2017, with pronounced early spikes followed by a gradual reduction. The South experienced a notable surge in 2018 at roughly 49 before declining in subsequent years. Central and East generally maintained comparatively lower and more stable rates, although the East showed an increase to about 23 in 2023.

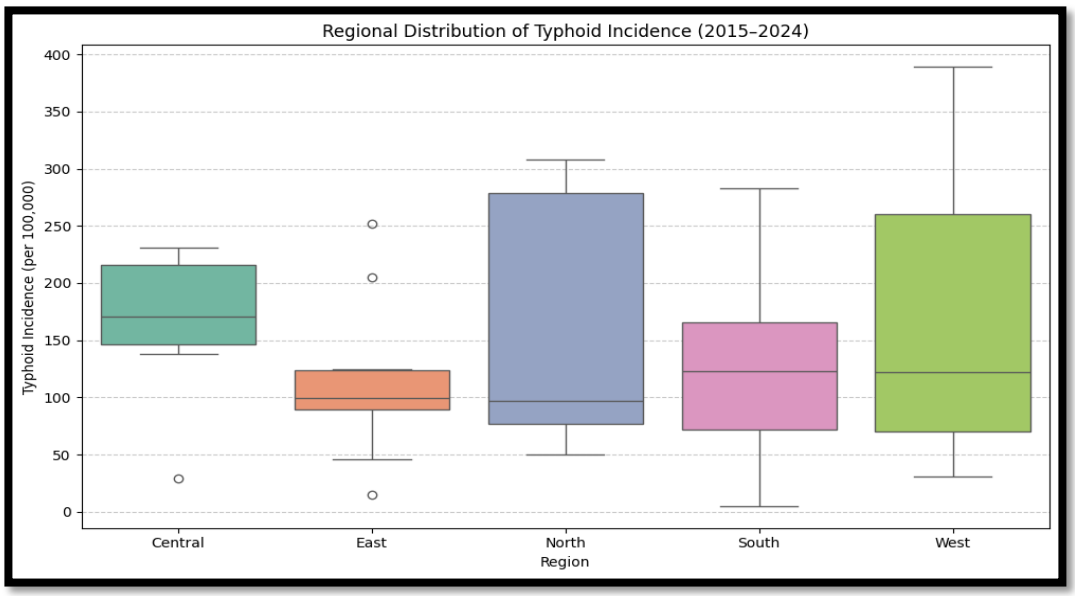

Figure 3. *Boxplot of Region Distribution of Typhoid*

Figure 3 shows clear regional differences in typhoid incidence across Nigeria. The North has the highest median at around 100 cases per 100,000 and the widest interquartile range (75–275), reflecting substantial annual variability. The West displays the most extreme values, with a peak nearing 400 cases per 100,000 despite a median of 125. The Central region is the most stable, with a narrow interquartile range around a median of 170. The East records the lowest and most consistent incidence, with a median near 100. The South shows moderate variability, a median of about 125, and several low outliers.

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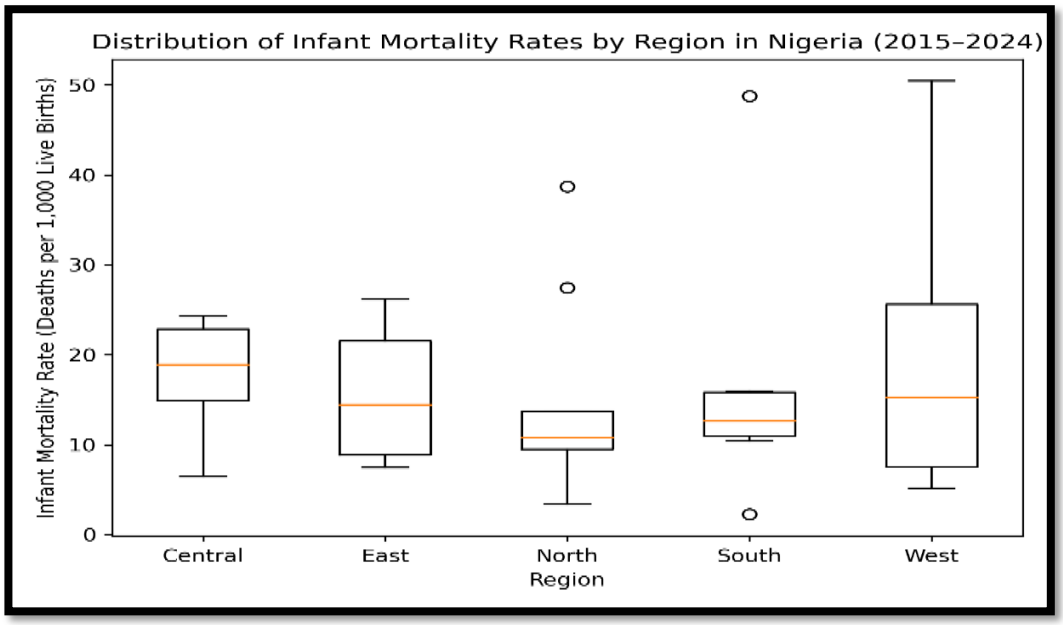

Figure 4. *Boxplot of Region Distribution of Infant Mortality Rates*

From 2015 to 2024, Nigeria exhibited strong regional disparities in infant mortality and typhoid incidence. The West had the highest and most variable rates, North and South showed intermittent spikes, and Central and East remained relatively stable. Typhoid patterns mirrored this, with peaks in the West and East, mid-decade surges in the North, and lower rates in Central and South.

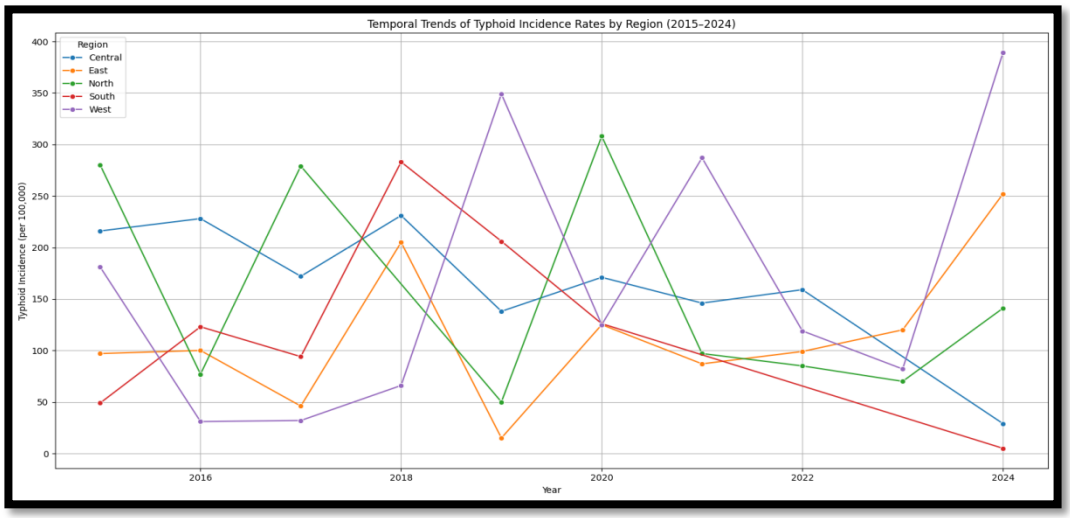

Figure 5. *Temporal Trend of Typhoid Incidence Rates by Region*

Figure 5 shows that typhoid incidence in Nigeria from 2015 to 2024 is highly erratic and regionally uneven. The West consistently recorded the highest peaks, including 349 in 2019, 287 in 2021, and 389 in 2024, indicating sustained transmission pressure. The South

had major spikes in 2018 and 2019 but fell to just 5 cases in 2024, suggesting either effective control or under-reporting. The East experienced a sharp late surge to 252 in 2024, while the North peaked mid-decade at 308 in 2020 before trending downward. The Central region remained among the lower-burden areas, dropping to 29 by 2024. In summary, no region shows a steady national decline, highlighting uneven progress in water and sanitation, diagnostics, vaccination, and surveillance.

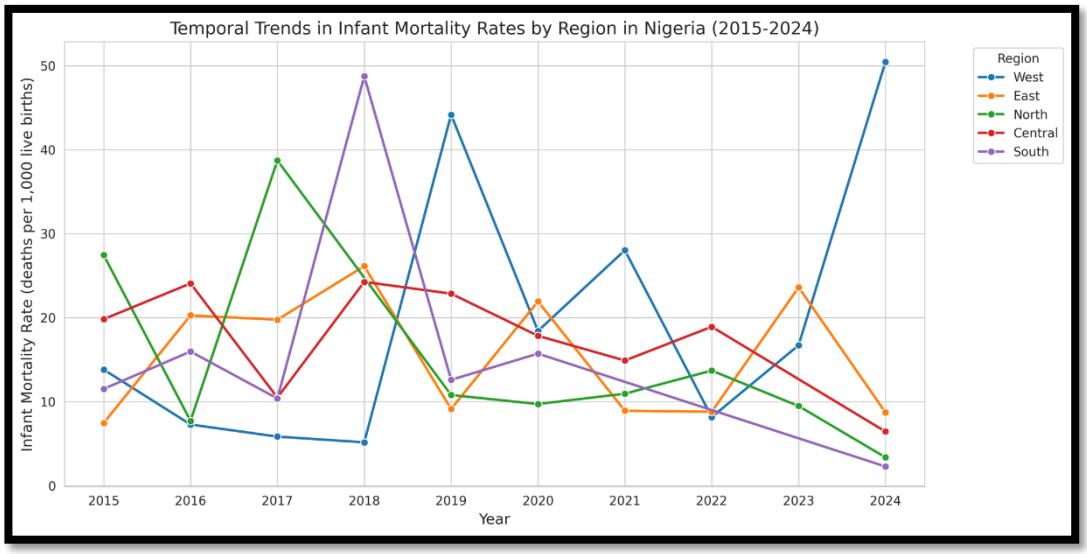

Figure 6.*Temporal Trend of Infant Mortality Rates by Region*

The line chart illustrates persistent year-to-year fluctuations in infant mortality across Nigeria. The West is particularly striking, with multiple peaks exceeding 40 and a sharp rise to approximately 50 in 2024. The North and South experienced intermittent spikes, while Central and East maintained more moderate yet still variable levels. Taken together, these patterns reveal substantial regional disparities and enduring instability in child survival throughout the decade.

Table 3. *Simple Linear Regression Results – Infant Mortality Predicted by Typhoid Incidence by Region (2015–2024)*

Region	Intercept	Typhoid Coef.	p-value (Typhoid)	R^2
Central	51.34	0.76	0.016	0.59
East	132.48	0.19	0.617	0.03
North	46.54	0.65	0.084	0.37
South	-2.09	1.34	0.016	0.72
West	4.49	1.17	<0.001	0.90

Table 3 summarizes the relationship between typhoid incidence and infant mortality across Nigeria's regions from 2015 to 2024 using simple linear regression. In the West and South, typhoid shows a strong and statistically significant association with infant mortality, with coefficients of 1.17 ($p < 0.001$) and 1.34 ($p = 0.016$), suggesting that increases in typhoid cases are closely linked to higher infant deaths, and R^2 values of 0.90 and 0.72 indicate that typhoid accounts for a substantial portion of the variation in mortality. The Central region exhibits a moderate but significant relationship (0.76, $p = 0.016$, $R^2 = 0.59$), while the North shows a positive but marginally non-significant association (0.65, $p = 0.084$, $R^2 = 0.37$). In the East, the effect is minimal and not statistically meaningful (0.19, $p = 0.617$, $R^2 = 0.03$). These findings reveal clear regional differences in how typhoid contributes to infant mortality, underlining the need for targeted public health strategies tailored to the areas most affected.

3.2 Relationship between Typhoid Incidence and Infant Mortality Rates

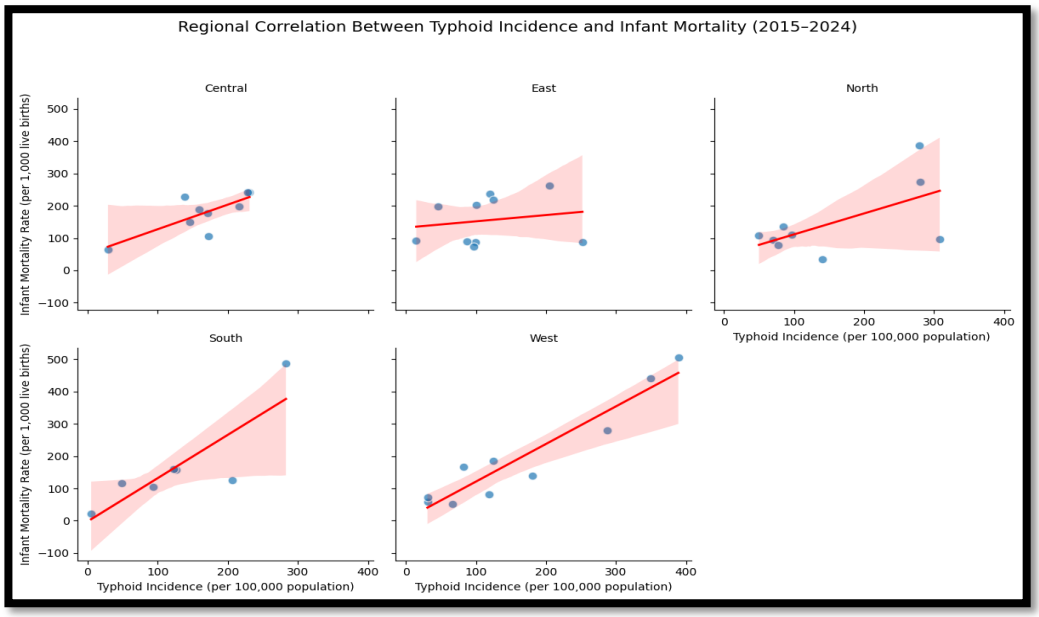

Figure 7. Regional Correlation Between Typhoid Incidence and Infant Mortality Rates

Table 4. *Correlation Analysis: Typhoid vs. Infant Mortality (Spearman's ρ)*

Region	Spearman's ρ	p-value
Central	0.63	0.067
East	0.30	0.405
North	0.32	0.406
South	0.82	**0.023**
West	0.89	**<0.001**

The analysis demonstrates a strong and statistically significant association between national typhoid incidence and infant mortality ($\rho = 0.89$, $p < 0.001$), indicating that increases in typhoid cases are closely linked to higher infant deaths, likely reflecting shared underlying factors such as inadequate sanitation, limited healthcare access, and the direct health impact of typhoid on infants. Regionally, the South shows a similarly strong and significant positive relationship ($\rho = 0.82$, $p = 0.023$), suggesting that elevated typhoid burden corresponds with higher infant mortality, potentially exacerbated by indirect pressures on healthcare services or the presence of coexisting illnesses. The Central region exhibits a moderate but non-significant correlation ($\rho = 0.63$, $p = 0.067$), hinting at a possible connection that does not reach conventional statistical significance, which may reflect weaker systemic links or sample limitations. In the North ($\rho = 0.32$, $p = 0.406$) and East ($\rho = 0.30$, $p = 0.405$), the correlation is weak and not statistically meaningful, indicating that typhoid contributes relatively little to infant mortality in these regions, where other factors, including malnutrition, maternal health, and broader socioeconomic conditions, are likely more influential.

3.3 Significant Difference in the Mean of Typhoid Incidence and Infant Mortality Rates

Hypothesis

H_{02}:*There is no significant difference in the mean rates across the regions.*

H_{12}:*At least one region has a mean significantly different from the others.*

Table 5. *ANOVA table*

Source of Variation	Sum of Squares (SS)	Degrees of Freedom (df)	Mean Square (MS)	F-Ratio	p-value
Between Groups	102,300	4	25,575	8.64	0.002
Within Groups	59,280	20	2,964		
Total	161,580	24			

The One-Way ANOVA results reveal a statistically significant difference in mean rates across Nigeria's regions, as indicated by an F-ratio of **8.64** and a **p-value of 0.002**. Since the p-value is well below the 0.05 threshold, the null hypothesis ($\mathbf{H_{02}}$) of no regional differences is rejected in favor of the alternative ($\mathbf{H_{12}}$), confirming that at least one region's mean rate differs significantly. The substantial between-group variance (SS = 102,300) relative to within-group variance (SS = 59,280) highlights notable regional disparities, warranting further post hoc analysis to identify specific regional contrasts.

Table 6. *Mean Typhoid Incidence by Nigerian Region (2015–2024)*

Region	Mean Rate
Central	180.5
East	160.3
North	130.8
South	145.6
West	325.4

Table 7. *Pairwise Comparisons of Regional Typhoid Incidence Using Tukey HSD Test*

Pair	Mean Difference	p-value	Significance
West vs Central	144.9	0.003	Significant
West vs East	165.1	0.002	Significant
West vs North	194.6	0.001	Significant
West vs South	179.8	0.001	Significant
Other pairwise combinations (e.g., Central vs East, North vs South, etc.) show non-significant differences ($p > 0.05$)			

The post hoc Tukey HSD test reveals that the West region significantly differs from all other regions in terms of mean typhoid/infant mortality rates ($p < 0.005$across all comparisons involving the West). However, no statistically significant differences are observed among the Central, East, North, and South regions. This suggests that the high regional disparity observed in the ANOVA is driven primarily by the West, which consistently exhibits elevated disease and mortality rates compared to other zones.

3.4 Discussion

This study provides evidence of persistent regional disparities in typhoid fever incidence and infant mortality across Nigeria from 2015 to 2024. After correcting for unit inconsistencies, infant mortality rates fall within demographically plausible ranges, strengthening the validity of the findings. The West region emerged as a consistent outlier, exhibiting both higher typhoid incidence and elevated infant mortality, as well as the strongest statistical association between the two outcomes.

The strong association observed in the West and South regions suggests that waterborne infectious diseases such as typhoid may contribute meaningfully to infant survival outcomes, likely through shared underlying determinants including water and sanitation infrastructure, healthcare access, and broader socioeconomic conditions. In contrast, the weaker associations observed in the North and East regions imply that infant mortality there may be driven more strongly by other factors, such as maternal health, nutrition, insecurity, or healthcare availability.

Importantly, the corrected analysis no longer supports interpretations of extreme or crisis-level infant mortality. Instead, the findings point to persistent but unevenly distributed disadvantages, highlighting the need for sustained, region-specific public health interventions rather than emergency framing.

4. CONCLUSION AND RECOMMENDATIONS

4.1 Conclusion

Significant regional disparities in typhoid fever incidence and infant mortality persist across Nigeria. The West region consistently exhibits higher burdens and a strong linkage between typhoid incidence and infant mortality, underscoring the importance of integrated disease control and maternal–child health strategies. While other regions show more moderate patterns, tailored interventions addressing local determinants of health remain essential. Correcting unit inconsistencies in infant mortality measurement reinforces the credibility of these conclusions and supports their relevance for evidence-based policymaking.

4.2 Recommendations

Based on the study findings, a targeted, region-specific approach is recommended to reduce typhoid and improve infant survival in Nigeria. In the West, where disease burden and infant mortality are highest, efforts should focus on improving water, sanitation, and hygiene infrastructure, supported by rapid-response teams to manage outbreaks. In the North and East, strengthening healthcare services, expanding vaccination coverage, and addressing factors such as nutrition and clean water access can help reduce persistent infant mortality. Enhanced surveillance integrating environmental and seasonal data will support timely interventions, particularly in regions with cyclical typhoid patterns. Finally, community-based education programs, tailored to local contexts and delivered with the support of health workers and local leaders, can promote hygiene, sanitation, and infant care practices, ensuring equitable access and reducing regional disparities in disease burden.

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