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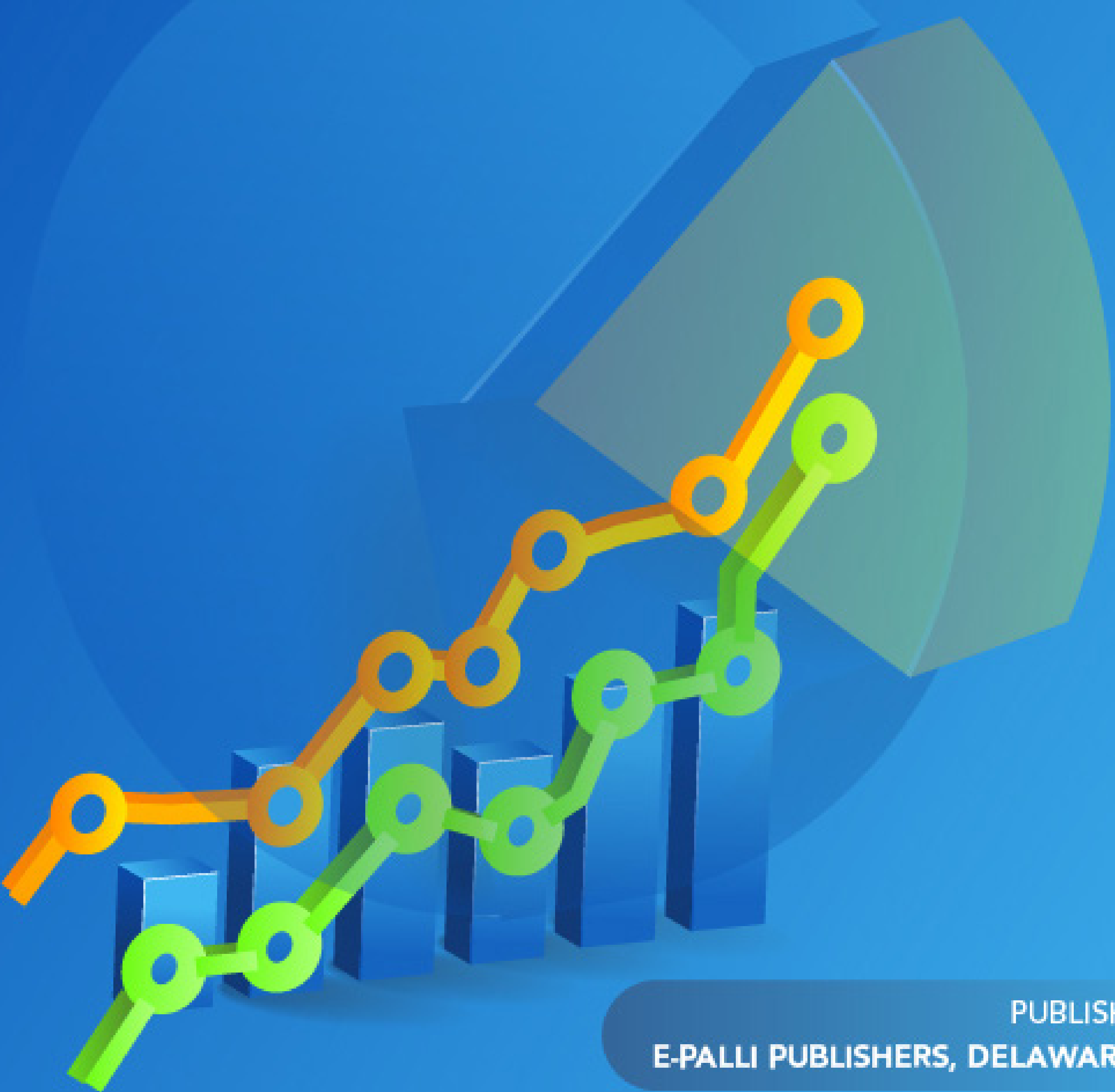

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Modelling the Determinants of Typhoid Fever in Benue State, Nigeria Using Binary Logistic Regression

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ABSTRACT

Typhoid fever remains a significant public health burden in Benue State, Nigeria, where unsafe water, poor sanitation, inadequate hygiene, and low vaccination coverage continue to fuel transmission. Despite its endemicity, rigorous statistical evidence identifying the key determinants of infection within the state's unique socio-environmental context remains limited. This study aimed to identify and quantify the independent predictors of typhoid fever in Benue State using binary logistic regression. The study adopted a descriptive and analytical cross-sectional design, utilizing secondary data from hospital records and epidemiological reports. After data cleaning and validation, researchers analyzed a total of 420 complete records obtained from Benue State University Teaching Hospital, Makurdi and related surveillance sources. The dependent variable was typhoid fever status (positive = 1; negative = 0). Independent variables included socio-demographic, environmental, household, behavioral, and clinical factors. Descriptive statistics, chi-square tests, and binary logistic regression were applied at a 5% significance level using standard statistical software. Of the 420 respondents, 168 (40.0%) tested positive for typhoid fever. Binary logistic regression identified ten significant independent predictors of infection. The strongest predictors were lack of typhoid vaccination (OR = 4.31; 95% CI: 2.21–8.41), poor handwashing practice (OR = 3.94; 95% CI: 2.06–7.53), uncovered water storage (OR = 3.49; 95% CI: 1.90–6.42), use of unimproved water sources (OR = 3.06; 95% CI: 1.71–5.47), and prior history of typhoid infection (OR = 2.97; 95% CI: 1.72–5.13). Additional significant predictors included unimproved toilet facilities (OR = 2.66), household size greater than five persons (OR = 2.44), age below 15 years (OR = 2.36); frequent eating outside the home (OR = 2.25); and low educational attainment (OR = 2.10). Sex was not a significant predictor. The model demonstrated good fit (Hosmer–Lemeshow $\chi^2 = 6.18$, $p = 0.63$), with Nagelkerke $R^2 = 0.51$ and an overall classification accuracy of 79.5% (sensitivity: 76.2%; specificity: 81.7%). Typhoid fever in Benue State is a multifactorial disease driven by behavioral, environmental, household, clinical, and socio-demographic factors. Effective control requires integrated water, sanitation, and hygiene (WASH) interventions, expanded vaccination programs, and targeted health education campaigns focused on high-risk populations.

INTRODUCTION

Typhoid fever, caused by Salmonella enterica serovar Typhi, remains a major public health problem in low- and middle-income countries, particularly across sub-Saharan Africa, where inadequate water supply, poor sanitation, and insufficient hygiene practices sustain transmission. Globally, an estimated 11–21 million cases occur annually, resulting in approximately 128,000–161,000 deaths, with children and young adults disproportionately affected (Gashaw & Jambo, 2022; O'Reilly *et al.,* 2020).

In Nigeria, typhoid fever is endemic, with Benue State particularly affected due to rapid urbanization, overcrowding, irregular access to clean water, and poorly developed waste disposal systems (Adikwu *et al.*, 2018). The disease burden in the state is further compounded by the emergence of antimicrobial-resistant strains, variability in diagnostic practices, and weak surveillance systems, making accurate identification of risk factors a public health priority (Asghar *et al.*, 2024; Okello *et al.*, 2011).

Although prior studies have described the epidemiology of typhoid fever in Nigeria, most rely on descriptive approaches, falling short of providing rigorous, context-specific statistical evidence on the key determinants of infection in Benue State. Identifying these determinants is critical for designing targeted interventions and evidence-based public health policies.

Binary logistic regression is an established and appropriate statistical tool for modeling dichotomous health outcomes such as typhoid infection status, enabling quantification of the odds of infection associated with multiple predictor variables while controlling for confounding factors (Saad *et al.*, 2025). Its application to typhoid fever epidemiology has been documented in several studies across endemic regions (Machamba *et al.*, 2022), yet its use within the specific context of Benue State remains limited.

This study, therefore, aimed to identify and quantify the independent determinants of typhoid fever in Benue State, Nigeria, using binary logistic regression, with a

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focus on socio-demographic, environmental, household, behavioral, and clinical factors. The findings are intended to provide empirical evidence to guide targeted and sustainable public health interventions for typhoid control in the state.

MATERIALS AND METHODS

Study Area: The study was conducted in Benue State, located in the North-Central geopolitical zone of Nigeria. The state has a tropical climate with distinct wet and dry seasons, a predominantly rural population largely engaged in agriculture, and urban centers such as Makurdi with varying levels of water and sanitation infrastructure. Benue State has a well-documented history of typhoid fever endemicity, with prevalence variations across local government areas reflecting diverse socio-demographic and environmental conditions (Adikwu *et al.*, 2018; Modu *et al.*, 2022).

Study Design and Setting: A descriptive and analytical cross-sectional research design was adopted. The study was set within secondary and tertiary health facilities in Benue State, primarily Benue State University Teaching Hospital (BSUTH), Makurdi, alongside relevant public health surveillance records and epidemiological reports. The cross-sectional design allowed simultaneous assessment of multiple independent variables in relation to typhoid infection status at a defined time point (Setia, 2016).

Population and Sample: The target population comprised individuals residing in Benue State who had been clinically evaluated or laboratory-tested for typhoid fever. These included patients attending hospitals, primary healthcare centers, and individuals captured in public health surveillance records. The population spanned all age groups, both sexes, diverse occupations, and varying socio-economic backgrounds, reflecting both rural and urban settings across the state.

Sample Size and Sampling Technique: Given the reliance on secondary data, a census sampling approach was adopted within the available datasets to maximize data utilization. After systematic extraction, cleaning, and validation, which involved excluding records with missing infection status or incomplete information on key explanatory variables, a final sample of 420 complete records was retained for analysis. Each record represented an individual evaluated for typhoid fever through clinical assessment and/or laboratory testing.

Data Collection: Data were collected entirely through systematic extraction of secondary data from hospital records, outpatient registers, laboratory-confirmed case reports, and epidemiological surveillance documents at BSUTH, Makurdi, and related sources. A structured data extraction template was developed to ensure consistency and completeness in capturing all relevant variables. Where multiple sources provided overlapping data, triangulation was applied to verify accuracy. All data were subsequently coded and structured into a dataset compatible with statistical software for analysis.

Variables: The dependent variable was typhoid fever infection status, coded dichotomously (Positive = 1; Negative = 0).

The independent variables were organized into five domains:

- Socio-demographic: age, sex, educational level, occupation
- Environmental: source of drinking water, type of toilet facility, waste disposal method
- Household: household size, water storage practice, overcrowding
- Behavioral: handwashing frequency after toilet use, use of soap, eating food prepared outside the home, water treatment practices
- Clinical: typhoid vaccination status, previous history of typhoid fever

Categorical variables were numerically coded and dummy variables were created where necessary, while continuous variables such as age and household size were retained in numeric form.

Statistical Analysis: All statistical analyses were performed using SPSS version 26 at a 5% level of significance ($p < 0.05$). The analytical process proceeded in three stages:

- Descriptive analysis: Frequencies and percentages were computed for categorical variables, while means and standard deviations were calculated for continuous variables.
- Bivariate analysis: Chi-square (χ^2) tests of independence were used to examine associations between each independent variable and typhoid fever status. Variables with $p < 0.05$ were considered for inclusion in the regression model.
- Binary logistic regression: A multivariate binary logistic regression model was fitted to identify independent predictors of typhoid fever. The model

$$logit(p) = ln((\frac{p}{1-p}) = \beta_0 + \beta_1 X_1 + \beta_2 X_2 + \cdots + \beta_k X_k)$$

took the form:

where p is the probability of typhoid infection, β_0 is the intercept, β_i are regression coefficients, and X_i are the independent variables. Exponentiated coefficients (e^{β}) were reported as odds ratios (OR) with 95% confidence intervals.

Model diagnostics included the Hosmer–Lemeshow goodness-of-fit test, Cox & Snell and Nagelkerke pseudo R^2 values, and a classification table reporting overall accuracy, sensitivity, and specificity. Multicollinearity was assessed using Variance Inflation Factor (VIF) values prior to model fitting.

Ethical Considerations: Since the study relied exclusively on secondary data, direct participant contact was not required. Confidentiality was maintained by excluding personal identifiers from the dataset. Individual records were assigned numerical codes, and data were stored in password-protected files accessible only to the research team. The study adhered to institutional ethical guidelines, and data were used in accordance with approved protocols from BSUTH, Makurdi.

RESULTS AND DISCUSSION

This section presents the findings from the statistical analysis of determinants of typhoid fever among 420 respondents in Benue State, Nigeria. Results are organized into: typhoid fever prevalence, socio-demographic characteristics, environmental and household conditions, behavioral and clinical profiles, bivariate associations, and binary logistic regression findings.

Typhoid Fever Status of Respondents

Of the 420 records analyzed 168 (40.0%) tested positive for typhoid fever and 252 (60.0%) were negative, indicating a substantially high disease prevalence among individuals presenting at health facilities in Benue State.

Table 1: Distribution of Respondents by Typhoid Fever Status

Typhoid Status	Frequency	Percentage (%)
Positive	168	40.0
Negative	252	60.0
Total	420	100.0

Socio-Demographic Characteristics of Respondents

The majority of respondents were young adults aged 25–34 years (26.7%), followed by those aged 15–24 years (22.4%). The gender distribution was nearly equal, with males constituting 51.0% and females 49.0%. Secondary education was the most common educational level (32.4%), while 21.9% had no formal education. Farmers (24.3%) and traders (22.9%) were the predominant occupational groups. This reflects the agrarian economic structure of Benue State (Edomah, 2019; Akighir *et al.*, 2020).

Environmental and Household Characteristics

More than half of respondents (58.1%) relied on unimproved water sources such as wells and rivers. Over half (52.9%) used unimproved toilet facilities, and 49.0% disposed of waste through open dumping. A majority (56.2%) lived in households with more than five persons, and 61.4% stored drinking water in uncovered containers, conditions highly conducive to typhoid transmission (Tadesse *et al.*, 2023).

Table 2: Socio-Demographic Characteristics of Respondents (N = 420)

Variable	**Category**	**Frequency**	**Percentage**
Age (years)	Below 15	68	16.2
	15–24	94	22.4
	25–34	112	26.7
	35–44	78	18.6
	45 and above	68	16.2
Sex	Male	214	51.0
	Female	206	49.0
Educational Level	No formal education	92	21.9
	Primary	118	28.1
	Secondary	136	32.4
	Tertiary	74	17.6
Occupation	Student	88	21.0
	Farmer	102	24.3
	Trader	96	22.9
	Civil servant	54	12.9
	Others	80	19.0

Behavioral and Hygiene Practices

Only 38.6% of respondents consistently washed their hands after toilet use, and only 32.9% always used soap. A majority (64.8%) did not treat water before drinking, and 41.4% frequently consumed food prepared outside the home, all recognized risk behaviors for typhoid infection (Gasem *et al.*, 2001; Kim *et al.*, 2023).

Clinical Characteristics

Most respondents (77.1%) had not received typhoid vaccination, while 30.0% reported a prior history of typhoid infection. Only 51.0% consistently completed prescribed antibiotic courses, raising concerns about incomplete treatment and potential antimicrobial resistance (Gupta & Deka, 2018).

Bivariate Analysis

Chi-square tests of independence were conducted to assess associations between independent variables and typhoid fever status. Results are presented in Tables 6 to

Table 3: Environmental and Household Characteristics of Respondents (N = 420)

Variable	Category	Frequency	Percentage (%)
Source of Drinking Water	Pipe-borne/Borehole	176	41.9
	Well/River	244	58.1
Toilet Facility	Improved	198	47.1
	Unimproved/Open	222	52.9
Waste Disposal Method	Government collection	104	24.8
	Open dumping	206	49.0
	Burning/Burying	110	26.2
Household Size	≤ 5 persons	184	43.8
	> 5 persons	236	56.2
Water Storage Practice	Covered container	162	38.6
	Uncovered container	258	61.4

Table 4: Behavioral and Hygiene Practices of Respondents (N = 420)

Variable	Category	Frequency	Percentage (%)
Handwashing After Toilet	Always	162	38.6
	Sometimes	148	35.2
	Rarely/Never	110	26.2
Use of Soap	Always	138	32.9
	Sometimes	162	38.6
	Never	120	28.5
Eating Food Outside Home	Frequently	174	41.4
	Occasionally	156	37.1
	Never	90	21.4
Water Treatment	Yes	148	35.2
	No	272	64.8

Table 5: Clinical Characteristics of Respondents (N = 420)

Variable	Category	Frequency	Percentage (%)
History of Typhoid Infection	Yes	126	30.0
	No	294	70.0
Typhoid Vaccination Status	Yes	96	22.9
	No	324	77.1
Completion of Prescribed Antibiotics	Yes	214	51.0
	No	206	49.0

9.
Age ($p = 0.012$) and educational level ($p = 0.001$) were significantly associated with typhoid fever. Sex was not significant ($p = 0.146$).
All four environmental and household variables were significantly associated with typhoid infection (all $p < 0.001$).
Both clinical variables, vaccination status and prior infection history, were significantly associated with typhoid fever ($p < 0.001$).
Binary Logistic Regression Analysis
Variables significant in bivariate analysis were entered into the binary logistic regression model. The dependent variable was typhoid infection status (1 = positive; 0 =

Table 6: Association between Socio-Demographic Factors and Typhoid Fever Status

Variable	Category	Typhoid Positive n (%)	Typhoid Negative n (%)	χ^2	p-value
Age Group	Below 15	36 (52.9)	32 (47.1)	12.84	0.012*
	15–24	44 (46.8)	50 (53.2)		
	25–34	38 (33.9)	74 (66.1)		
	≥ 35	50 (34.5)	96 (65.5)		
Sex	Male	94 (43.9)	120 (56.1)	2.11	0.146
	Female	74 (35.9)	132 (64.1)		
Education	No formal	48 (52.2)	44 (47.8)	16.27	0.001*
	Primary	52 (44.1)	66 (55.9)		
	Secondary	46 (33.8)	90 (66.2)		
	Tertiary	22 (29.7)	52 (70.3)		

**Significant at* $p < 0.05$

Table 7: Association Between Environmental/Household Factors and Typhoid Fever Status

Variable	Category	Typhoid Positive n (%)	Typhoid Negative n (%)	χ^2	p-value
Water Source	Pipe/Borehole	48 (27.3)	128 (72.7)	29.64	<0.001*
	Well/River	120 (49.2)	124 (50.8)		
Toilet	Improved	56 (28.3)	142 (71.7)	31.88	<0.001*
Facility					
	Unimproved	112 (50.5)	110 (49.5)		
Household Size	≤ 5 persons	52 (28.3)	132 (71.7)	26.75	<0.001*
	> 5 persons	116 (49.2)	120 (50.8)		
Water Storage	Covered	42 (25.9)	120 (74.1)	34.09	<0.001*
	Uncovered	126 (48.8)	132 (51.2)		

**Significant at* $p < 0.05$

Table 8: Association Between Behavioral Practices and Typhoid Fever Status

Variable	Category	Typhoid Positive n (%)	Typhoid Negative n (%)	χ^2	p-value
Handwashing After Toilet	Always	38 (23.5)	124 (76.5)	41.62	<0.001*
	Sometimes/ Rarely	130 (50.4)	128 (49.6)		
Use of Soap	Always	30 (21.7)	108 (78.3)	39.08	<0.001*
	Sometimes/ Never	138 (49.3)	144 (50.7)		
Eating Away From Home	Frequently	94 (54.0)	80 (46.0)	22.51	<0.001*
	Occasionally/ Never	74 (30.3)	172 (69.7)		

Table 9: Association Between Clinical Factors and Typhoid Fever Status

Variable	Category	Typhoid Positive n (%)	Typhoid Negative n (%)	χ^2	p-value
Handwashing After Toilet	Yes	18 (18.8)	78 (81.2)	21.44	<0.001*
	No	150 (46.3)	174 (53.7)		
Use of Soap	Yes	72 (57.1)	54 (42.9)	25.18	<0.001*
	No	96 (32.7)	198 (67.3)		

**Significant at* $p < 0.05$

negative).

Ten independent variables were significant predictors of typhoid fever. The strongest predictors were lack of vaccination (OR = 4.31), poor handwashing (OR = 3.94), uncovered water storage (OR = 3.49), use of unimproved water sources (OR = 3.06), and previous typhoid infection (OR = 2.97). Sex was not a significant predictor and was excluded from the final model (Saad *et al.*, 2025; Khanam *et al.*, 2025).

Table 10: Binary Logistic Regression Analysis of Determinants of Typhoid Fever (N = 420)

Variable	β	SE	Wald	p-value	Odds Ratio (Exp β)	95% CI for OR
Age (<15 years)	0.86	0.32	7.23	0.007*	2.36	1.27 – 4.39
Low education	0.74	0.28	6.99	0.008*	2.10	1.22 – 3.61
Unimproved water source	1.12	0.30	13.86	<0.001*	3.06	1.71 – 5.47
Unimproved toilet	0.98	0.29	11.41	0.001*	2.66	1.51 – 4.69
Household size >5	0.89	0.27	10.87	0.001*	2.44	1.43 – 4.16
Uncovered water storage	1.25	0.31	16.17	<0.001*	3.49	1.90 – 6.42
Poor handwashing practice	1.37	0.33	17.24	<0.001*	3.94	2.06 – 7.53
Frequent eating outside	0.81	0.29	7.82	0.005*	2.25	1.29 – 3.95
Not vaccinated	1.46	0.34	18.51	<0.001*	4.31	2.21 – 8.41
Previous typhoid infection	1.09	0.28	15.06	<0.001*	2.97	1.72 – 5.13
Constant	-3.12	0.61	26.18	<0.001	–	–

**Significant at* $p < 0.05$

Model Goodness-of-Fit and Predictive Accuracy

The logistic regression model demonstrated satisfactory fit and strong predictive ability.

The non-significant Hosmer–Lemeshow result (p = 0.63) confirmed adequate model fit. The Nagelkerke R^2 of 0.51 indicated that the model explained approximately 51% of the variation in typhoid infection status. An overall accuracy of 79.5%, with sensitivity of 76.2% and specificity of 81.7%, confirmed the model's reliable discriminatory ability between infected and non-infected individuals.

Table 11: Model Goodness-of-Fit Statistics

Diagnostic Measure	Value
Hosmer–Lemeshow χ^2	6.18
Hosmer–Lemeshow p-value	0.63 (non-significant, good fit)
Cox & Snell R^2	0.38
Nagelkerke R^2	0.51
Overall Classification Accuracy	79.5%
Sensitivity	76.2%
Specificity	81.7%

Discussion

This study identified a 40.0% prevalence of typhoid fever among 420 respondents in Benue State, consistent with endemic patterns across sub-Saharan Africa (Adikwu *et al.*, 2018; Meiring *et al.*, 2023).

Socio-Demographic Factors: Age below 15 years (OR = 2.36) and low educational attainment (OR = 2.10) significantly predicted infection, reflecting vulnerability due to immature immunity and limited hygiene awareness (Muche *et al.*, 2024; Tadesse *et al.*, 2022). Sex was not significant ($p = 0.146$).

Environmental Factors: Use of unimproved water sources (OR = 3.06) and unimproved sanitation (OR = 2.66) were strong predictors, confirming the critical role of contaminated water and poor sanitation in fecal-oral transmission (Antillón *et al.*, 2017; Yushananta & Putri, 2024).

Household Factors: Household size greater than five persons and uncovered water storage significantly increased infection risk, highlighting the importance of household-level hygiene education (Tadesse *et al.*, 2023).

Behavioral Factors: Poor handwashing was a significant predictor, underscoring the need for hygiene promotion and food safety enforcement (Okyere *et al.*, 2025). Frequent eating outside the home (OR = 2.2) was also a significant predictor (Novia *et al.*, 2021).

Clinical Factors: Lack of vaccination was the strongest predictor, with 77.1% of respondents unvaccinated. Prior typhoid infection also elevated risk, raising concerns about reinfection and antimicrobial resistance (Tanmoy *et al.*, 2018).

Model Performance: The model demonstrated good fit (Hosmer–Lemeshow $p = 0.63$), with Nagelkerke $R^2 = 0.51$ and classification accuracy of 79.5% (sensitivity: 76.2%; specificity: 81.7%).

CONCLUSION

Typhoid fever remains a major public health burden in Benue State, driven by ten independent predictors spanning behavioral, environmental, household, clinical, and socio-demographic domains. Lack of vaccination, poor handwashing, unsafe water storage, and unimproved water sources were the strongest risk factors. Sustainable control requires an integrated strategy encompassing WASH improvements, expanded vaccination, hygiene education, and food safety regulation. This study demonstrates the utility of binary logistic regression in generating actionable, evidence-based insights for public health intervention in endemic settings.

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