ORIGINAL ARTICLE

EPIDEMIOLOGY AND RISK FACTORS FOR TYPHOID FEVER IN GOMBE METROPOLIS, GOMBE STATE, NIGERIA

Umar Abdullahi Tawfiq[1,3], Shamarina Shohaimi[1*], Syafinaz Amin-Nordin[2], Mohd Noor Hisham Mohd Nadzir[1], Abdul Hafiz Ab Rahman[4] and Nader Salari[5]

[1]Department of Biology, Faculty of Science, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[2]Department of Medical Microbiology, Faculty of Medicine and Health Sciences, Universiti Putra Malaysia, 43400 UPM Serdang, Selangor, Malaysia
[3]Department of Microbiology, Gombe State University, 760214 Tudun Wada, Gombe, Gombe State, Nigeria
[4]Faculty of Social Sciences and Humanities, Universiti Kebangsaan Malaysia, 43600 UKM Bangi, Selangor, Malaysia
[5]Department of Biostatistics, School of Public Health, Kermanshah University of Medical Sciences, 6715847141, Kermanshah, Iran

***Corresponding Author: Shamarina Shohaimi**
Email: shamarina@upm.edu.my

ABSTRACT

There is limited data on typhoid in Gombe, Nigeria, despite the high prevalence of the disease in the area. A lack of epidemiological data has hampered efforts to control the disease. This study aims to identify factors associated with the increased risk of typhoid infection and recurrence in the Gombe metropolis. This study used simple random sampling, and data were collected from 663 consenting respondents using a validated questionnaire. Data were analysed using the Chi-square test to determine risk factors for typhoid occurrence and binomial logistic regression to determine factors for recurrence. Typhoid occurrences were significantly associated with vaccine hesitancy, having a houseboy or girl, not washing hands before handling food, low level of education, drinking unboiled water, eating commercially available foods or drinks, and having typhoid carrier at home. Respondents who were 'not sure of being vaccinated' (OR = 2.856, 95% CI 1.493-5.465), 'do not have another typhoid patient at home' (OR = 1.739, 95% CI 1.093-2.766), were more likely to have typhoid recurrences while those with 'secondary school level education' and 'drank boiled water' were less likely to have recurrences (OR = 0.480 95% CI: 0.234-0.982 and OR = 0.473, 95% CI: 0.266-0.842 respectively). These findings could be used as guidelines for future interventions against typhoid, maximising resource efficiency and improving the overall quality of life.

Keywords: *Nigeria, Occurrence, Recurrence, Risk Factors, Typhoid*

INTRODUCTION

Typhoid fever is a human-specific disease caused by the gram-negative *Salmonella typhi* bacterium. It is most commonly contracted through consuming food or drink contaminated with the faeces or urine of *S. typhi*-shedding carriers, who are typically asymptomatic[1]. Enteric fever, another name for typhoid fever, is characterised by a high fever that lasts for several days and is accompanied by a wide range of symptoms, including nausea, vomiting, diarrhoea, paradoxical bradycardia, muscle atrophy, and a lack of appetite. It can result in haemorrhage, peritonitis, encephalopathy, and intestinal perforations, all of which are fatal if not treated promptly[2].

Typhoid is a leading cause of death and disease morbidity, with The World Health Organisation reporting over 25 million cases yearly [3]. In 2000, 2.6 million typhoid cases were reported worldwide and 216,500 deaths [4]. The figure increased to 11 million cases with almost 9 million disability-adjusted life-years (DALYs) and more than 127,000 deaths in 2016[5,] and in 2017, the number further increased to approximately 9.9 to 24.2 million cases and 75,000 to 208,000 deaths. However, data is scarce in low- and middle-income countries[6].

Other analyses of S. typhi infections revealed that in 2017, there were more than 100 infections per 100,000 people among populations in Southern Africa and Asian countries, indicating a high rate of occurrence of this disease [7,8]. Moreover, according to the CDC, over half of all sporadic cases of food poisoning between 2006 and 2017 were caused by the typhoid pathogen and approximately half of these illnesses were caused by eating raw farm products. This situation has prompted an investigation that discovered that untreated water was used in the irrigation of these farms, most likely the source and spreading agent of the typhoid pathogen in those farm products[9].Before the emergence of the COVID-19 pandemic, Pakistani public health authorities had documented totalities of more than 22,500 S. typhi infections in Sindh populations between November 2016 and the middle of February 2020. Of these occurrences, 16,000 tested positive for the new extensively drug-resistant (XDR) S. typhi, amid an increasing prevalence of XDR S. typhi[10].

Despite progress in some areas of typhoid control, this disease remains a major public health issue around the world[11]. Therefore, it is critical to understand the impact of S. typhi infections on the world's economy. It was previously estimated that this bacterium caused more than 10,000,000 infections and more than 100,000 deaths in 2017, mainly among the very young and elderly and among the poor, particularly in parts of Asia and Africa[13] and other developing countries.

Many developing countries face information gaps on health problems caused by typhoid fever[14]. In addition, data on typhoid in specific communities is scarce, limited to underdeveloped areas, and only in a few cases properly documented. Given the possibility of more efficient vaccines, more emphasis should be placed on identifying typhoid fever risk factors based on geographic locations to develop and implement appropriate immunisation schedules[15].

Typhoid fever among the population in Gombe State, Nigeria, has not been well documented. This situation hiders the effort to identify the most at risk and may explain the infection's persistence and the failure of any control policy. As a result, it is difficult to determine the most effective targeted health interventions and the form and scale of such interventions. Therefore, this study aims to identify typhoid infection and recurrence risk factors in the Gombe metropolis. The findings of this study can be used to identify at-risk populations and help guide the appropriate prevention and control efforts.

METHODS

Study design and location

The study was a cross-sectional study[16] that involved patients with laboratory-confirmed typhoid fever in the study area. Information regarding previous laboratory-confirmed occurrences of typhoid among the respondents was obtained to determine if the respondent has been diagnosed with typhoid or has a recurrent infection. State Specialist Gombe Hospital was chosen for this research because it is the main hospital patronised by a considerable portion of the population living in the metropolis. The hospital is also accessible and has relatively good quality diagnostic equipment compared to other state-owned health facilities. The data for this study were collected from August 9 to November 30, 2019.

Data source

A questionnaire was designed, validated, and distributed to obtain data on the exposure and outcome from consenting patients in the study area. The questionnaire is self-administered unless the respondent requested otherwise. Only fully completed questionnaires were retained for analysis. The data from these questionnaires were then defined into suitable categorical or continuous variables before analyses[17].

Questionnaire design

The questionnaire was adapted from typhoid questionnaires and forms from previous studies, including the "Typhoid fever outbreak investigation"[18], "CRF: Case and control enrolment questionnaire"[19], and "Enhanced typhoid and paratyphoid surveillance questionnaire"[20]. Some locally observed variables associated with typhoid risk were added to the questionnaire. The draft questionnaire, which was subsequently approved by the Gombe State Ministry of Health, was tested in a pilot study involving twenty typhoid patients in Gombe State Specialist Hospital to identify vague or unclear questions[21]. The instrument's readability was tested using the Flesch reading ease test and Flesch-Kincaid grade level test in the proofing option in Microsoft Office Word 2016[22]. Moreover, Fleiss' Multi-rater kappa[23]was used to determine its content validity, the test-retest method with Intra-class Correlation Coefficient[24] was utilised for reliability testing, and the instrument's construct validity was determined using Cronbach's alpha[25] and McDonald's omega coefficients[26]. The validated questionnaire used for this study[27] contained numerous items which measured demographic, socioeconomic, and behavioural variables, such as occupation, crowdedness at home, and consumption of food/drink outside the home, respectively.

Sample size determination and sample collection

The sample size for this study was determined to be 663 at a 95% confidence interval and 5% acceptable margin of error, using the Statcalc in Epi Info v 7.2.2.6 software of Centres for Disease Control and Prevention[28]. The 95% confidence limit was set to ensure the study's findings have sufficient statistical power[29]. The simple random sampling method was used to identify respondents with laboratory-confirmed typhoid fever in the study area[30].

Host-associated risk factors

Typhoid risk can be directly linked to a person's hygiene and sanitation practices and how they handle food, their attitude and practice towards hygiene and sanitation, and the type of food they eat. These factors are known as host-associated risk factors[31]. Hence, data on the host-associated risk factors were collected using the validated questionnaire.

Incidence and recurrence proportions

The incidence and recurrence of typhoid fever were estimated using data compiled from hospital laboratory reports and patient questionnaires. Total incidence and recurrence per 100,000 individuals were calculated by dividing confirmed cases by the metropolis's population and multiplying by 100,000[32].

$$\text{Incidence/recurrence proportion} = \left(\frac{n}{N}\right) \times 100{,}000$$

where: n = total confirmed typhoid cases and N = total population in the study area

The incidence and recurrence values were adjusted to account for the 73% determined sensitivity of the Widal test used in the study area laboratory before calculating the incidence proportions. The Widal test's sensitivity was determined by collecting stool samples from 100 Widal-positive respondents, culturing them on Salmonella-Shigella (SS) agar, and recording visible Salmonella growths represented by black-centred colonies on the SS agar[33].

Data analysis

The methods used to analyse the data were chosen based on the nature and distribution of the data, the predicted association between the variables, and the assumptions of the statistical tests[34].

Chi-square test of association

The chi-square test of association (x^2) at a significance level of $p < 0.05$ was conducted to determine if the host-associated risk variables are significantly associated with typhoid fever's overall occurrence in the study area. Before conducting the chi-square test, the test assumptions were checked[35]. This analysis was conducted using SPSS Version 26 for Windows.

Logistic regression

Binomial logistic regression was carried out on the risk factors variables significantly associated with overall typhoid occurrence to determine which categories of these variables were significant predictors of typhoid recurrence[36]. Assumptions for logistic regression were checked before executing the test[36]. This analysis was conducted using SPSS Version 26 for Windows.

Ethical approval

The ethical approval for this research (reference number: MOH/ADM/S/658/VOL/II/122) was obtained from the Gombe State Ministry of Health. Informed written consent was obtained from each respondent unless requested otherwise by the respondent. All questionnaires were distributed and collected anonymously in sealed envelopes. The researcher ensured no labels or information linking the respondents with the data were present to protect their anonymity. Each questionnaire was discreetly handled by the researcher alone to further protect the confidentiality of the data.

RESULTS

Validated questionnaire

The validated questionnaire has a Flesch reading ease test value of 70.8 and a Flesch-Kincaid grade level test score of 6.0. Regarding content validity, it has a Fleiss' kappa value of 0.623, while the internal consistency is reflected by Cronbach's alpha value of 0.720 and the McDonald's omega of 0.703. Lastly, the test-retest reliability ICC estimate is 0.736

Distribution of respondents by demography

The characteristics of the respondents included in the study are shown in Table 1. More than half of the respondents are male (51.7%) and aged between 18 to 35 years old (55.1%). Half of the respondents are semi-skilled professionals (45.2%%), and 15% are unemployed.

Number of Incidences and recurrence cases

In terms of confirmed typhoid cases, this study found that between 2015 and 2019, there were 9116 confirmed typhoid cases per 100,000 persons in the study area. The highest incidence was recorded in 2018 with 2555 cases per 100,000 persons per year, while the lowest incidence was reported in 2016 with 1351 cases per 100,000 persons per year. In the meantime, typhoid recurrence or relapse refers to the repeated occurrence of typhoid on an individual. The number of recurrent cases could only be determined for 2019 because the retrospective data source does not contain information regarding the patients' previous typhoid fever history. In this light, there were 126 confirmed recurrent cases per 100,000 persons in the study area between January and November 2019. For each month, the confirmed typhoid recurrent cases per 100,000 persons were as follows: January = 5, February = 10, March = 5, April = 7, May = 6, June = 11, July = 15, August = 57, September = 3, October = 4, and November = 3. Furthermore, as shown in Figure 1, the monthly typhoid incidences from 2015 to 2019 in Gombe Metropolis revealed that typhoid cases mostly peaked in October.

Distribution of typhoid counts by gender

The distribution of typhoid counts by gender is shown in Table 2. In general, typhoid cases are more prevalent among females than males.

Distribution of typhoid counts by age

The distribution of typhoid counts by age (Table 3) revealed that individuals aged 21 to 30 recorded the highest typhoid occurrences in the study area.

Chi-square test of association between risk variables and typhoid

The results of the chi-square test for the association between the predictor variables and the typhoid outcome (Table 4) revealed that vaccine hesitancy, having a house boy or girl, not washing hands before handling food, low education level, drinking unboiled water, eating commercially available foods or drinks, and having typhoid carrier at home have statistically significant associations with typhoid occurrence

Table 1: Distribution of respondents by demography

Variable	Category	Frequency	Percentage
Gender	Male	343	51.7
	Female	320	48.3
Age (years)	9 to 17	83	12.5
	18 to 35	365	55.1
	36 to 55	150	22.6
	56 to 65	43	6.5
	66 to 85	19	2.9
	86 to 100	3	0.5
Occupation	Skilled Professional	108	16.4
	Semi-Skilled Professional	300	45.2
	Unskilled Professional	86	13.0
	Student	70	10.7
	Not working	99	15.0
Marital Status	Single	369	55.7
	Married	266	40.1
	Divorced	28	4.2

Table 2: Distribution of typhoid counts by gender

		GENDER		Total
		Male	**Female**	
	2015	3713 (60.9%)	2382 (39.1%)	6095 (100%)
	2016	2509 (48.4%)	2676 (51.6%)	5185 (100%)
YEAR	**2017**	2531 (48.3%)	2707 (51.7%)	5238 (100%)
	2018	4577 (46.7%)	5226 (53.3%)	9803 (100%)
	2019	4677 (54.0%)	3980 (46.0%)	8657 (100%)
Total		18007 (51.5%)	16971 (48.5%)	34978 (100%)

Table 3: Distribution of typhoid counts by age

	Yearly averages					5 years total
Age groups	**2015**	**2016**	**2017**	**2018**	**2019**	
0-10	1029 (16.9%)	835 (16.1%)	672 (12.8%)	2108 (21.5%)	1957 (22.6%)	6601 (18.9%)
11-20	1459 (23.9%)	1318 (25.4%)	1258 (24.0%)	2530 (25.8%)	2231 (25.8%)	8796 (25.1%)
21-30	1798 (29.5%)	1689 (32.6%)	1658 (31.7%)	2888 (29.5%)	2540 (29.3%)	10573 (30.2%)
31-40	770 (12.6%)	639 (12.3%)	764 (14.6%)	1099 (11.2%)	871 (10.1%)	4143 (11.8%)
41-50	462 (7.6%)	380 (7.3%)	421 (8.0%)	581 (5.9%)	534 (6.1%)	2378 (6.8%)
51-60	330 (5.4%)	177 (3.4%)	248 (4.7%)	333 (3.4%)	275 (3.2%)	1363 (3.9%)
61-70	148 (2.4%)	96 (1.9%)	153 (3.0%)	164 (1.7%)	164 (1.9%)	725 (2.1%)
71-80	76 (1.3%)	41 (0.8%)	52 (1.0%)	66 (0.7%)	65 (0.8%)	300 (0.9%)
81-90	18 (0.3%)	6 (0.1%)	6 (0.1%)	20 (0.2%)	18 (0.2%)	68 (0.2%)
91-100	5 (0.1%)	4 (0.1%)	6 (0.1%)	13 (0.1%)	2 (0.0%)	30 (0.1%)
101-110	0 (0.0%)	0 (0.0%)	0 (0.0%)	1 (0.0%)	0 (0.0%)	1 (0.0%)
TOTAL	6095 (100%)	5185 (100%)	5238 (100%)	9803 (100%)	8657 (100%)	34978 (100%)

Table 4: Chi-square test for association between exposure variables and typhoid outcome

Predictor variables	Chi-square	df	Significance
Vaccine hesitancy	39.729	4	p = 0.042
Having a house boy or girl	16.909	4	p = 0.002
Other typhoid cases at home	13.393	4	p = 0.010
Not washing hands with soap before handling food	22.856	4	p = 0.000
Consuming iced or frozen items	16.805	4	p = 0.002
Not boiling water before drinking	49.633	4	p = 0.000
Eating commercial foods or drinks	27.864	4	p = 0.000
Typhoid carrier at home	11.986	4	p = 0.017
Tiles on the kitchen floor	8.666	4	p = 0.070
Type of kitchen	9.178	6	p = 0.164
Toilets or faeces near a water source	2.303	4	p = 0.680
Hands-on farming	2.769	4	p = 0.597
Level of education	18.239	8	p = 0.020
Other treatments for drinking water	0.086	4	p = 0.999
Sharing eating utensils at the same time	9.463	4	p = 0.051
Attending mass gatherings	10.801	4	p = 0.029
Collecting any food items from the river near the main road	8.771	4	p = 0.067
Using public toilets	9.520	4	p = 0.049

Note: df, degree of freedom

Table 5: Values for the categories of variables in the logistic regression

Categories	Sig.	Exp(B)	95% CI for Exp(B)	
			Lower	Upper
Typhoid vaccination	.001			
Typhoid vaccination (1: not sure)	.002	2.856	1.493	5.465
Typhoid vaccination (2: no)	.642	.897	.566	1.420
Having househelp	.128			
Having househelp (1: sometimes)	.071	1.506	.965	2.348
Having househelp (2: no)	.155	1.511	.856	2.668
Other typhoid cases at home	.039			
Other typhoid cases at home (1: not sure)	.045	1.685	1.012	2.804
Other typhoid cases at home (2: no)	.019	1.739	1.093	2.766
Hands soap-wash before handling food	.405			
Hands soap-wash before handling food (1: sometimes)	.750	1.106	.596	2.052
Hands soap-wash before handling food (2: no)	.406	.789	.452	1.379
Level of education	.362			
Level of education (1: bachelor's degree)	.071	.522	.258	1.056
Level of education (2: secondary)	.045	.480	.234	.982
Level of education (3: primary)	.251	.587	.236	1.458
Level of education (4: none)	.148	.480	.178	1.296
Consume iced or frozen products	.816			
Consume iced or frozen products (1: sometimes)	.873	.961	.592	1.560
Consume iced or frozen products (2: no)	.523	.846	.507	1.412
Consume anything in a mass gathering attended	.032			
Consume anything in a mass gathering attended (1: not sure)	.056	1.678	.988	2.850
Consume anything in a mass gathering attended (2: no)	.012	1.790	1.134	2.827
Boil water before drinking	.017			
Boil water before drinking (1: sometimes)	.011	.473	.266	.842
Boil water before drinking (2: always)	.014	.500	.287	.871
Eat commercial foods/drinks	.104			
Eat commercial foods/drinks (1: sometimes)	.111	1.685	.887	3.200
Eat commercial foods/drinks (2: no)	.599	.870	.516	1.464
Use public toilets	.011			
Use public toilets (1: sometimes)	.145	.708	.444	1.127
Use public toilets (2: no)	.106	1.494	.918	2.431

Note: CI, confidence interval; Exp(B), exponentiation of B coefficient; sig., significance

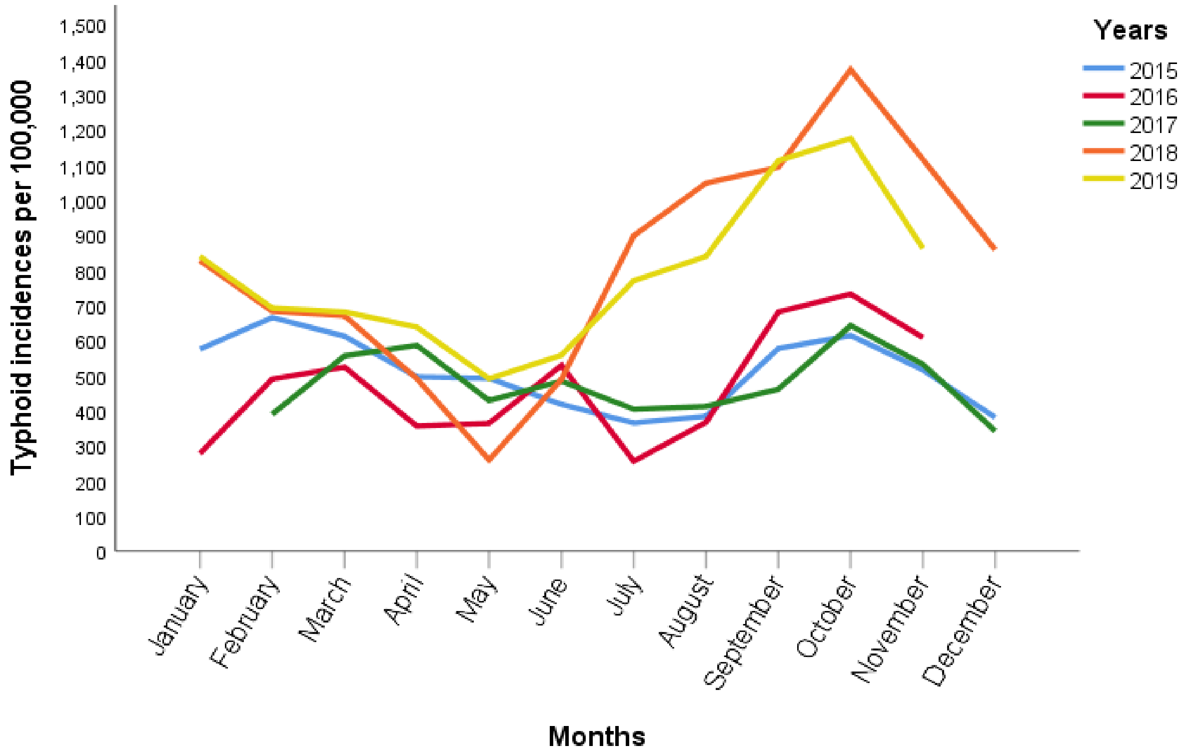

Figure 1: Monthly typhoid incidences in Gombe Metropolis, Nigeria, from 2015 to 2019

Logistic regression for predicting typhoid recurrence risk factors

The outcome of the logistic regression analysis showed that the model has x^2 (df = 22, n = 663) = 92.063 with $p < 0.05$, Nagelkerke $R^2 = 0.189$, Hosmer and Lemeshow x^2 (df = 8, n = 663) = 8.259 with $p > 0.05$, block 0 classification table with 73.50% correctness, and block 1 classification table with 75.90% correctness.

The values for categories of the variables in the logistic regression equation (Table 5) showed that 'not sure of being vaccinated' and 'do not have another typhoid patient at home' are more likely to predict typhoid recurrences while 'secondary school level education' and 'drink boiled water' are more likely to protect against typhoid recurrences.

DISCUSSION

Questionnaire validation

At the end of the validation steps, the final questionnaires' readability was determined as 'easy' based on the interpretation of the Flesch reading ease test value and Flesch-Kincaid grade level test score. This finding implied that based on the interpretive criteria described in Bello et al.[22], the instrument could be read and understood by anyone with 4th to 6th-grade education and above. The findings also indicated that the questionnaire's content validity is good. Based on the description of content validity[37], these results reflect that the items in the questionnaire are a good representative of the total theoretical constructs of the questionnaire intent to evaluate the variables. Moreover, based on the interpretive criteria in Trizano-Hermosilla & Alvarado[38], the questionnaire has a good internal consistency with alpha and omega values greater than 0.70, which are acceptable for instrument construct validity and internal consistency. Lastly, the instrument also showed a good test-retest reliability ICC estimate, based on guidelines documented by Koo & Li[24].

Occurrences of typhoid fever

The data on monthly typhoid occurrences revealed that typhoid cases peaked in October. This is believed to be because the minimum temperature gradually increases in October, proceeding with the peak rainfall in August. Both rainfall and temperature have been associated with the elevation of typhoid cases[39], and the two weeks average incubation period of the typhoid pathogen accounts for the delay in elevation of cases possibly contracted since August or early October[40]. These findings align with Morral-Puigmal et al.41 and Indhumathi & Kumar42, who also reported how upward drifts in weather conditions increase typhoid cases.

Occurrences of typhoid by gender

The higher typhoid occurrences among females in the Gombe metropolis are believed to be due to common gender-specific activities and behaviours involving females in the study area, which put them at greater risk of typhoid than males. Females in the study area usually attend mass gatherings that serve food and drinks locally prepared by other women and their house helpers. The lack of knowledge about hygienic food preparation and handling among these food handlers can lead to the food being contaminated with *Salmonella typhi*. Furthermore, some of them might even be typhoid carriers [43–46].

Occurrences of typhoid by age

The pattern of typhoid occurrences based on age groups observed in this study is in line with the work of Rasul et al.[47], which reported the highest occurrence of typhoid in Punjab, Pakistan, is among individuals aged between 21 to 30. Allu et al.[48] also reported the highest occurrence of typhoid among people aged between 21 to 30 in Duhok, Iraq. This may be because people in this age group are more prone to unsanitary life routines, higher junk food consumption, and more frequent attendance at social gatherings.

Association between risk variables and typhoid occurrence

The significant association between vaccine hesitancy and typhoid fever is likely due to the widespread misconceptions and beliefs among the local population that vaccines are used in a conspiracy to depopulate the community, cause infertility among women, and expose children to life-threatening diseases that will manifest in adulthood. These misconceptions and beliefs have resulted in high vaccine hesitancy and even refusal, which have become the primary impediments to immunisation schedules in several Nigerian states, including Gombe[49,50].

Moreover, the presence of a house boy or girl (househelp) is also linked to the occurrence of typhoid as these house helpers could be healthy carriers of the typhoid pathogen. As house helpers customarily prepare and handle food in many households in the study area, they could actively contaminate food during its preparation and serving [51]. There is also an increased risk of typhoid infection if another typhoid patient is in the house. This is especially evident when the patient share

Toilets and food items with others. This situation can lead to direct or indirect contact with the typhoid patient and subsequent exposure to the pathogen, which has a relatively low infectious dose[52].

Typhoid fever is also statistically associated with not washing hands with soap before touching food. The lack of a clean water supply has hindered proper hand washing[53]. As the hands and fingers play the most important roles in the faecal-oral transmission of the typhoid pathogen, improper handwashing, or lack thereof, may be the cause of typhoid disease[54].

The study also found an association between not boiling water before drinking and typhoid fever in this study [55,56]. In this regard, drinking unclean or unboiled water from poorly maintained wells, commercially marketed jerrycan water, water trucks, and water sachets, and using unboiled water for other purposes like making ice blocks contribute to typhoid fever occurrences. Similarly, the statistically significant association between consuming commercially available foods and drinks with typhoid fever could be due to large numbers of workers and students patronising food vendors primarily in unsanitary environments, unhygienic plates and utensils cleaning practices, and unhygienic food preparation, handling and serving processes[57].

Typhoid recurrence risk factors

The results of the logistic regression revealed that category one (not sure) under the typhoid vaccination variable had $p < 0.05$ and Exp(B) value of 2.856 with 95% CI values of 1.493 to 5.465. These findings indicate that individuals who are unsure of being vaccinated against typhoid within the last two years are more likely to have typhoid recurrence than individuals who are sure of being vaccinated. Therefore, not being sure of being vaccinated has a statistically significant association with the likelihood of typhoid recurrence by an average of 2.856 times, varying between 1.493 and 5.465 times.

These findings agree with Bilcke et al. [58] study, which projected that routine immunisation programs against typhoid could result in a 30% decline in typhoid occurrences over 120 months. Another significant variable is the presence of another (previous) typhoid patient at home. In this light, individuals who are unsure of the presence of another (previous) typhoid patient at home and those not living with another (previous) typhoid patient at home are more likely to have a recurrence of typhoid than those living with another (previous) typhoid patient. This is based on the logistic regression outcomes for the 'not sure' and 'no' categories under having another typhoid patient at home. The 'not sure' category recorded $p < 0.05$ and an Exp(B) value of 1.685 with 95% CI values of 1.012 to 2.804, while the 'no' category recorded $p < 0.05$ and an Exp(B) value of 1.739 with 95% CI values 1.093 to 2.766. These findings showed that these individuals have 1.685 times ('not sure' category) and 1.739 times ('no' category) more likely to have typhoid recurrence than individuals living with another (previous) typhoid patient. This may be because having another typhoid patient at home allows other household members to gain more knowledge about typhoid, how it is transmitted, and how to avoid infection by the pathogen[59].

Individuals who boil water 'sometimes' and 'always' before drinking are less likely to have typhoid recurrence than individuals who do not boil water before drinking. This could be due to the unboiled water being contaminated with the typhoid pathogen[60].

All interpretations of the logistic regression output were derived from the works of Hinton[61] and Kleinbaum and Klein[62]. In the meantime, this study has several limitations. For instance, some typhoid patients were too ill to respond to the requests to participate in the study. However, this is thought to have no effect on the study's outcome because the severity of the patients' symptoms is believed to be caused by their delayed visit to the hospital.

CONCLUSION

Typhoid occurrences in the Gombe metropolis are epidemiologically high for both genders and almost all age groups. This is associated with vaccine hesitancy, having a house boy or girl, among others, while recurrences of the disease are more likely to occur among those uncertain about their vaccination status and not having another typhoid patient at home, among others. The findings of this study can be used to identify individuals with a higher risk of contracting typhoid, and this information can be used to develop and implement preventative and control strategies that are both effective and efficient.

ACKNOWLEDGEMENT

The Authors hereby acknowledge Alh. Umar Bappah; for his efforts during the ethical clearance, and Roseline Sadat; for her assistance during the data collection.

Competing interests
None.

Funding
The authors received no specific funding for this work.

REFERENCES

1. Masuet-Aumatell C, Atouguia J. Typhoid fever infection – antibiotic resistance and vaccination strategies: a narrative review. *Travel Med Infect Dis*. 2020;40:101946. doi:10.1016/j.tmaid.2020.101946.

2. Tahira M, Nawaz H, Majeed MI, et al. Surface-enhanced Raman spectroscopy analysis of serum samples of typhoid patients of different stages. *Photodiagnosis Photodyn Ther*. 2021;34:102329. doi:10.1016/j.pdpdt.2021.102329.

3. Ndako JA, Dojumo VT, Akinwumi JA, Fajobi VO, Owolabi AO, Olatinsu O. Changes in some haematological parameters in typhoid fever patients attending Landmark University Medical Center, Omuaran-Nigeria. *Heliyon*. 2020;6(5):e04002. doi:10.1016/j.heliyon.2020.e04002.

4. Bhan MK, Bahl R, Sazawal S, et al. Association between Helicobacter pylori Infection and Increased Risk of Typhoid Fever. *J Infect Dis*. 2002;186(12):1857-1860. doi:10.1086/345762.

5. Crump JA. Progress in Typhoid Fever Epidemiology. *Clin Infect Dis*. 2019;68(Supplement_1): S4-S9. doi:10.1093/cid/ciy846.

6. Antillón M, Warren JL, Crawford FW, et al. The burden of typhoid fever in low- and middle-income countries: A meta-regression approach. Carvalho MS, ed. *PLoS Negl Trop Dis*. 2017;11(2):e0005376. doi:10.1371/journal.pntd.0005376.

7. Manesh A, Meltzer E, Jin C, et al. Typhoid and paratyphoid fever: a clinical seminar. *J Travel Med*. 2021;28(3):1-13. doi:10.1093/JTM/TAAB012.

8. Paul UK, Bandyopadhyay A. Typhoid fever: a review. *Int J Adv Med*. 2017;4(2):300. doi:10.18203/2349-3933.ijam20171035.

9. Liu H, Whitehouse CA, Li B. Presence and Persistence of Salmonella in Water: The Impact on Microbial Quality of Water and Food Safety. *Front public Heal*. 2018;6:159. doi:10.3389/fpubh.2018.00159.

10. Ahmad S, Tsagkaris C, Aborode AT, et al. A skeleton in the closet: The implications of COVID-19 on XDR strain of typhoid in Pakistan. *Public Heal Pract*. 2021;2:100084. doi:10.1016/j.puhip.2021.100084.

11. Feng Y, Chen Y-C, Janapatla RP, et al. Genomic surveillance reveals international circulation and local transmission of Salmonella enterica serovars Typhi and Paratyphi A in Taiwan. *J Microbiol Immunol Infect*. Published online July 8, 2021. doi:10.1016/J.JMII.2021.06.004.

12. Stanaway JD, Reiner RC, Blacker BF, et al. The global burden of typhoid and paratyphoid fevers: a systematic analysis for the Global Burden of Disease Study 2017. *Lancet Infect Dis*. 2019;19(4):369-381. doi:10.1016/S1473-3099(18)30685-6.

13. Marchello CS, Hong CY, Crump JA. Global Typhoid Fever Incidence: A Systematic Review and Meta-analysis. *Clin Infect Dis*. 2019;68(Supplement_2):S105-S116. doi:10.1093/cid/ciy1094.

14. Obaro SK, Iroh Tam P-Y, Mintz ED. The unrecognised burden of typhoid fever. *Expert Rev Vaccines*. 2017;16(3):249-260. doi:10.1080/14760584.2017.1255553.

15. Lee J-S, Mogasale V V., Mogasale V, Lee K. Geographical distribution of typhoid risk factors in low and middle income countries. *BMC Infect Dis*. 2016;16(1):732. doi:10.1186/s12879-016-2074-1.

16. CDC. Principles of Epidemiology | Lesson 1 - Section 10. *Cdc*. Published online 2020. Accessed March 6, 2021. https://www.cdc.gov/csels/dsepd/ss1978/lesson1/section8.html.

17. Oguntade ES, Shohaimi S, Nallapan M, Ajibola Lamidi-Sarumoh A. *Factors Influencing Malaria Knowledge, Attitude and Practice in Gwagwalada*. Vol 3.; 2018. Accessed February 4, 2019. www.ijshr.com.

18. Brainard J, D'hondt R, Ali E, et al. Typhoid fever outbreak in the Democratic Republic of Congo: Case-control and ecological study. Crump JA, ed. *PLoS Negl Trop Dis*. 2018;12(10):e0006795. doi:10.1371/journal.pntd.0006795.

19. Jenkins AP. A nested environmental approach to typhoid epidemiology in Central Division, Fiji. Published online 2017:206. https://ro.ecu.edu.au/cgi/viewcontent.cgi?article=2994&context=theses.

20. Outbreak Response Unit, National Institute for Communicable Diseases. *Outbreak Response Unit National Institute for Communicable Diseases*.; 2016.

21. Setia MS. Methodology series module 9: Designing questionnaires and clinical record forms-Part II. *Indian J Dermatol*. 2017;62(3):258-261. doi:10.4103/ijd.IJD_200_17.

22. Bello OW, Bello OW, Oyekunle A, Adeyemi R. Analysis of the Privacy Policies of Nigerian Online Shops. *Int J Inf Process Commun*. 2018;6(2):347-361. Accessed February 17, 2019. https://www.researchgate.net/publication/329872094.

23. McHugh ML. Interrater reliability: The kappa statistic. *Biochem Medica*. 2012;22(3):276-282. doi:10.11613/bm.2012.031.

24. Koo TK, Li MY. A Guideline of Selecting and Reporting Intraclass Correlation Coefficients for Reliability Research. *J Chiropr Med*. 2016;15(2):155-163. doi:10.1016/j.jcm.2016.02.012.

25. Taber KS. The Use of Cronbach's Alpha When Developing and Reporting Research Instruments in Science Education. *Res Sci Educ*. 2018;48(6):1273-1296. doi:10.1007/s11165-016-9602-2.

26. Hayes AF, Coutts JJ. Use Omega Rather than Cronbach's Alpha for Estimating Reliability. But…. *Commun Methods Meas*. Published online 2020. doi:10.1080/19312458.2020.1718629.

27. Tawfiq UA, Shohaimi S, Mohd Nadzir NH, Amin Nordin S, Ab Rahman AH, Salari N. Validity and Reliability of Typhoid Risk Factors Questionnaire (TRFQ) in Gombe Metropolis, Gombe State, Nigeria. *Pertanika J Sci Technol*. 2022;30(3):2007-2021. doi:10.47836/pjst.30.3.13.

28. CDC. Epi Info™| CDC. Centers for Disease Control and Prevention.

Published 2020. Accessed March 5, 2021. https://www.cdc.gov/epiinfo/index.html.

29. Faber J, Fonseca LM. How sample size influences research outcomes. *Dental Press J Orthod*. 2014;19(4):27-29. doi:10.1590/2176-9451.19.4.027-029.ebo.

30. Kipruto Bett D, Njogu P, Karanja B. Assessment of Occupational Safety and Health Awareness and Practices in Public Health Facilities Uasin Gishu County, Kenya. *IOSR J Dent Med Sci e-ISSN*. 2019;18:42-50. doi:10.9790/0853-1808014250.

31. Centers for Disease Control. Frequently Asked Questions | Social Determinants of Health | NCHHSTP | CDC. Published 2019. Accessed April 5, 2020. https://www.cdc.gov/nchhstp/socialdeterminants/faq.html.

32. Centre for Disease Control and Prevention USA. *Principles of Epidemiology in Public Health Practice, Third Edition: An Introduction*.; 2012. doi:S0171-9335(05)00209-8 [pii]\r10.1016/j.ejcb.2005.11.004.

33. Mawazo A, Bwire GM, Matee MIN. Performance of Widal test and stool culture in the diagnosis of typhoid fever among suspected patients in Dar es Salaam, Tanzania. *BMC Res Notes*. 2019;12(1). doi:10.1186/s13104-019-4340-y.

34. Mishra P, Pandey C, Singh U, Keshri A, Sabaretnam M. Selection of appropriate statistical methods for data analysis. *Ann Card Anaesth*. 2019;22(3):297-301. doi:10.4103/aca.ACA_248_18.

35. McHugh ML. The Chi-square test of independence. *Biochem Medica*. Published online 2013:143-149. doi:10.11613/BM.2013.018.

36. Stoltzfus JC. Logistic regression: A brief primer. *Acad Emerg Med*. 2011;18(10):1099-1104. doi:10.1111/j.1553-2712.2011.01185.x.

37. Tsang S, Royse CF, Terkawi AS. Guidelines for developing, translating, and validating a questionnaire in perioperative and pain medicine. *Saudi J Anaesth*. 2017;11(Suppl 1): S80-S89. doi:10.4103/sja.SJA_203_17.

38. Trizano-Hermosilla I, Alvarado JM. Best Alternatives to Cronbach's Alpha Reliability in Realistic Conditions: Congeneric and Asymmetrical Measurements. *Front Psychol*. 2016;7(MAY):769. doi:10.3389/fpsyg.2016.00769.

39. Dewan AM, Corner R, Hashizume M, Ongee ET. Typhoid Fever and Its Association with Environmental Factors in the Dhaka Metropolitan Area of Bangladesh: A Spatial and Time-Series Approach. *PLoS Negl Trop Dis*. 2013;7(1):1998. doi:10.1371/journal.pntd.0001998.

40. Awofisayo-Okuyelu A, McCarthy N, Mgbakor I, Hall I. Incubation period of typhoidal salmonellosis: a systematic review and meta-analysis of outbreaks and experimental studies occurring over the last century. *BMC Infect Dis*. 2018;18(1). doi:10.1186/s12879-018-3391-3.

41. Morral-Puigmal C, Martínez-Solanas È, Villanueva CM, Basagaña X. Weather and gastrointestinal disease in Spain: A retrospective time series regression study. *Environ Int*. 2018;121:649-657. doi:10.1016/j.envint.2018.10.003.

42. Indhumathi K, Sathesh Kumar K. A review on prediction of seasonal diseases based on climate change using big data. *Mater Today Proc*. Published online 2020. doi:10.1016/j.matpr.2020.08.517.

43. AYAZ C, LOEB M, GEYIK MF, et al. Risk factors for typhoid fever among adult patients in Diyarbakir, Turkey. *Epidemiol Infect*. 2005;134(03):612. doi:10.1017/s0950268805005583.

44. Burnsed LJ, Kovar LD, Angelo KM, et al. Use of whole genome sequencing to complement characterisation of a typhoid fever outbreak among a Marshallese community: Oklahoma, 2015. *Epidemiol Infect*. 2019;147(e11):1-7. doi:10.1017/S0950268818002601.

45. Hancock-Allen J, Cronquist AB, Peden J, Adamson D, Corral N, Brown K. Notes

from the Field: Typhoid Fever Outbreak Associated with an Asymptomatic Carrier at a Restaurant — Weld County, Colorado, 2015. *MMWR Morb Mortal Wkly Rep*. 2016;65(23):606-607. doi:10.15585/mmwr.mm6523a4.

46. Sur D, Ali M, Von Seidlein L, et al. Comparisons of predictors for typhoid and paratyphoid fever in Kolkata, India. *BMC Public Health*. 2007;7:1-10. doi:10.1186/1471-2458-7-289.

47. Rasul F, Sughra K, Mushtaq A, Zeeshan N, Mehmood S, Rashid U. Surveillance report on typhoid fever epidemiology and risk factor assessment in district Gujrat, Punjab, Pakistan. *Biomed Res*. 2017;28(16). Accessed October 14, 2020. https://www.biomedres.info/biomedical-research/surveillance-report-on-typhoid-fever-epidemiology-and-risk-factor-assessment-in-district-gujrat-punjab-pakistan-8198.html.

48. Allu MA, Assafi MS, Polse RF, Al- MI. Present status of Salmonella Typhi in different age groups hospitalised patients in Duhok City, Iraq. *Zanco J Pure Appl Sci*. 2019;31(6). doi:10.21271/zjpas.31.6.13.

49. Cobos Muñoz D, Monzón Llamas L, Bosch-Capblanch X. Exposing concerns about vaccination in low- and middle-income countries: a systematic review. *Int J Public Health*. 2015;60(7):767-780. doi:10.1007/s00038-015-0715-6.

50. WHO. Nigeria consolidates efforts to curtail vaccine hesitancy | WHO | Regional Office for Africa. WHO Africa. Published 2020. Accessed October 12, 2020. https://www.afro.who.int/news/nigeria-consolidates-efforts-curtail-vaccine-hesitancy.

51. Sivaji I, Duraisamy S, Balakrishnan S. Analysis of TLR polymorphisms in typhoid patients and asymptomatic typhoid carriers among the schoolchildren. *Egypt J Med Hum Genet*. 2016;17(4):353-357. doi:10.1016/j.ejmhg.2015.12.010.

52. Jaroni D. *Salmonella: Salmonella Typhi*. Vol 3. Second Edi. Elsevier; 2014. doi:10.1016/B978-0-12-384730-0.00296-2.

53. Gutbi S, Mohammed S, Eldinn N, Elhassan E, Abdalla AA. Perceived Barriers of Hands Washing Practices during Coronavirus (COVID-19) Outbreak (Sudan). *Int J Multidiscip Res Publ*. 2020;3(1):100-104.

54. Khan MI, Ochiai RL, Soofi SB, et al. Risk factors associated with typhoid fever in children aged 2-16 years in Karachi, Pakistan. *Epidemiol Infect*. 2012;140(4):665-672. doi:10.1017/S0950268811000938.

55. Abdullahi A, Abdu A. Household Water Conditions in Gombe : A Profile of Water Scarcity in Nassarawo , Palliative and Mitigation Measures. *Am Sci Res J Eng Technol Sci*. 2018;43(1):227-240. Accessed October 14, 2020. http://asrjetsjournal.org/.

56. Ishaku HT, Majid MR, Johar F. Rainwater Harvesting: An Alternative to Safe Water Supply in Nigerian Rural Communities. *Water Resour Manag*. 2012;26(2):295-305. doi:10.1007/s11269-011-9918-7.

57. Yakubu Madaki M, Bavorova M. Food safety knowledge of food vendors of higher educational institutions in Bauchi state, Nigeria. *Food Control*. 2019;106:106703. doi:10.1016/j.foodcont.2019.06.029.

58. Bilcke J, Antillón M, Pieters Z, et al. Cost-effectiveness of routine and campaign use of typhoid Vi-conjugate vaccine in Gavi-eligible countries: a modelling study. *Lancet Infect Dis*. 2019;19(7):728-739. doi:10.1016/S1473-3099(18)30804-1.

59. Getachew D, Wale B, Eshete W, et al. *Assessment of Knowledge and Risk Perception towards Typhoid Fever among Communities in Mendida Town*. Vol 7.; 2018.

60. Delpla I, Legay C, Proulx F, Rodriguez MJ. Perception of tap water quality: Assessment of the factors modifying the links between satisfaction and water consumption behavior. *Sci Total Environ*. 2020;722:137786. doi:10.1016/j.scitotenv.2020.137786.

61. Hinton P. *SPSS Explained*Hinton P, McMurray I, & Brownlow C. (2014). SPSS Explained (2nd ed.). New York:

Routledge. https://doi.org/10.4324/9781315797298.

62. Kleinbaum DG, Klein M. *Logistic Regression: A Self-Learning Text*. 3rd ed. Springer; 2010.