ORIGINAL RESEARCH ARTICLE

Typhoid Incidence and Environmental (Weather) Determinants in Gombe Municipality Gombe Nigeria: A Five-Year Epidemiological Study

Umar Abdullahi Tawfiq*[1] , Mofio Bintu Muhammad[2] , Tukur Muhammad Adamu[1] , Hanifa Mohammed[1] , Fatima Saleh[1]

[1]Microbiology Department, Faculty of Science, Gombe State University, Gombe, Nigeria
[2]Department of Biochemistry, University of Abuja, Gwagwalada, FCT, Nigeria

ABSTRACT

This study investigates the incidence of typhoid in Gombe Municipality over five years and examines the impact of weather conditions on these incidences, providing new insights into the epidemiology of typhoid in this region. Typhoid incidence data were obtained from the State Specialist Hospital, while weather data were obtained from the Nigeria Meteorological Agency. Incidences were determined using the incidence proportion method and adjusted to the 73% determined efficiency of the laboratory tests and discovered to be >100/100,000 persons/year, which is interpreted as high. Results also revealed more populated areas had higher typhoid incidences. Poisson regression analysis was used to fit and analyze weather and hospital data. The results showed that increases in minimum temperature by 1°C (OR = 1.080, CI = 1.048 to 1.114, $p < 0.01$) and humidity by 5% (OR = 1.041, CI = 1.031 to 1.051, $p < 0.01$) significantly predicted elevations in typhoid incidences. These findings are believed to guide the implementation of targeted health interventions against typhoid in the study area.

INTRODUCTION

Typhoid fever, caused by *Salmonella* typhi, remains a significant health issue in regions with poor sanitation (Mike *et al.*, 2017). This study aims to determine the incidence of typhoid in Gombe Municipality and investigate the influence of weather conditions on these incidences, filling a critical gap in the epidemiological data for this region.

Salmonella spp. has recently been relatively common in a few areas of Nigeria (Odikamnoro et al., 2017). Agu et al. (2015) reported a high overall death rate from the disease, while Adabara et al. (2012) reported a high prevalence of the illness in children aged one to ten. Overall, there hasn't been much comprehensive data on the epidemiology of typhoid disease in Nigeria (Wong et al., 2016), and it's not available in many of the nation's states. Knowing where to find and comprehend this data is essential for focusing public health efforts on interventions for typhoid disease prevention and control (Crump et al., 2004).

Being one of the main bacterial diseases affecting people, particularly in the sub-Saharan Africa region where rates of morbidity and death are high, typhoid fever has emerged as a severe health issue requiring immediate and sustained actions by health authorities (Masuet-Aumatell

and Atouguia, 2021). Due to the incompetent efforts of several agencies, Nigeria is among the countries in West Africa with inadequate water supplies and unhygienic practices. This results in low water quality and the consequent development of water-borne illnesses like typhoid fever (Adeyinka *et al.*, 2014). It is thought that the 12 million cases and more than 128,000 deaths from typhoid fever that are reported annually around the world are understated due to poor epidemiological information (Techasaensiri *et al.*, 2018).

Furthermore, accurate estimates of the disease's burden are essential for building an investment case for disease prevention and control initiatives. Moreover, for nations to follow the WHO's recent recommendations regarding the use of typhoid vaccines, a thorough understanding of the disease's epidemiology at both the national and state levels is necessary (Crump, 2015).

The shifts in weather conditions, like a temperature rise, lead to a rise in drinking cold water, frozen beverages, and other domestically produced traditional beverages. However, unfortunately, a lot of such consumables are variables that positively influence the spread of *S.* typhi due to its ability to survive in cold temperatures and the

unhygienic methods involved in the production and handling of such consumables (Siddiqui *et al.*, 2006). Frozen beverages can play important roles in manifestations of *S.* typhi infections (Awofisayo-Okuyelu *et al.*, 2018) due to the contaminated water utilized during their production processes (Wilson *et al.*, 2012) along with the pathogen's capability of enduring very cold environments as low as two degrees Celsius because it possesses cold shock proteins (CSPs) which it uses in rapid acclimatization to cold surroundings. These proteins emerge in the bacteria during shifts in temperature between thirty to ten degrees Celsius, which enables such a pathogen to subsequently continue growing when conditions become favorable and cause typhoid fever to an individual that consumes the item containing this bacterium (Andino and Hanning, 2015). An analysis involving risk factors for *S.* typhi transmission revealed that an increase of one degree Celsius in environmental temperature could be responsible for up to a fourteen percent rise in *S.* typhi infections in Dhaka, Bangladesh (Dewan *et al.*, 2013a).

There are surprisingly few research papers on the epidemiology of typhoid in Gombe State, Nigeria. These articles' limited sample sizes and narrow geographic coverage make them judged insufficient and imprecise because it is well known that without sufficient epidemiological data, the true extent of a disease cannot be determined, and as a result, a proper target population for health interventions and the type and scale of such interventions cannot be determined. This is thought to have contributed to the ongoing occurrences and spread of the disease as well as the ineffectiveness of any control strategies that may have been in place. Because of these, this study was set up to determine the incidences of typhoid fever in the Gombe metropolis from 2015 to 2019 and to ascertain whether weather conditions affect such typhoid incidences. This research, the first of its kind in Gombe State, Nigeria, will provide public health information that will serve as further evidence of the significance of the one health approach to disease control and prevention, which will further justify the need for strengthening this one health approach by Government and other stakeholders to improve the health of the population. This study will also complement similar international studies in countries like Bangladesh and Malawi, and nationally in parts of Nigeria like Kaduna, Anambra, and Kwara States.

MATERIALS AND METHODS

Ethics

The Gombe State Ministry of Health Headquarters provided ethical approval for this study under reference number MOH/ADM/S/658/VOL/II/122. Protocols for maintaining anonymity, gathering and managing anonymous data, and conducting ethical research were all followed.

Study Location

The "State Specialist Hospital Gombe" was the location chosen for this study. It was chosen based on the following factors: it is easily accessible, close to populated metropolitan areas, and has reasonably good diagnostic processes and equipment. It is also frequently visited by a significant portion of the local population.

State Specialist Hospital Gombe is located at latitude 10.2883° N and longitude 11.1790° E (HFR, 2019), at the heart of the Gombe metropolis (Figure 1), the States' capital, the seat of the head office of Gombe Local Government, and the major municipal center of Gombe State encompassing 5,200 km² in area, with a population of about 268,536 which has been proposed to reach beyond 280,000 individuals (Abdullahi *et al.*, 2017). Yearly rainfall has been reported to fluctuate from 560 to 740 mm (Hati and Dimari, 2011), with elevated relative humidity levels of 94% in August and decreased relative humidity of 10% in December (Lawal *et al.*, 2015). In 2019, the population of Gombe metropolis was reported to have risen to 489,000 (Population Stat, 2021).

Data Sources

The Gombe State Specialist Hospital's laboratory-confirmed typhoid fever case records from 2015 to 2019 provided the incidence statistics. The only patient information included in the data was age, gender, and the findings of their typhoid investigation; daily weather data for the same years was collected from the Nigeria Meteorological Agency (NIMET) Headquarters in Abuja, Nigeria. The meteorological data gathered comprised wind, temperature, humidity, and rainfall information.

Data Analysis: Typhoid incidence and recurrence

Hospital laboratory records were compiled to determine typhoid fever incidence and recurrence proportions (Jombo *et al.*, 2019). The formula below illustrates how the total confirmed cases were divided by the city's population and multiplied by 100,000 to calculate the overall incidence and recurrence per 100,000 people (John *et al.*, 2016).

Incidence/recurrence proportion = $\left(\frac{n}{N}\right) \times 100,000$, where: n = total confirmed typhoid cases and N = total population in 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 (achieved by comparing stool culture and the Widal test for 100 samples) before calculating the incidence proportions (Mawazo *et al.*, 2019). Because there were only positive typhoid cases in the data available, the dependent variable only had one category and could not be analyzed using inferential statistics. As a result, the distribution patterns of typhoid based on gender, age, and location were studied using bar charts and an overlay on a map of the metropolitan area (Ranjeeth *et al.*, 2020).
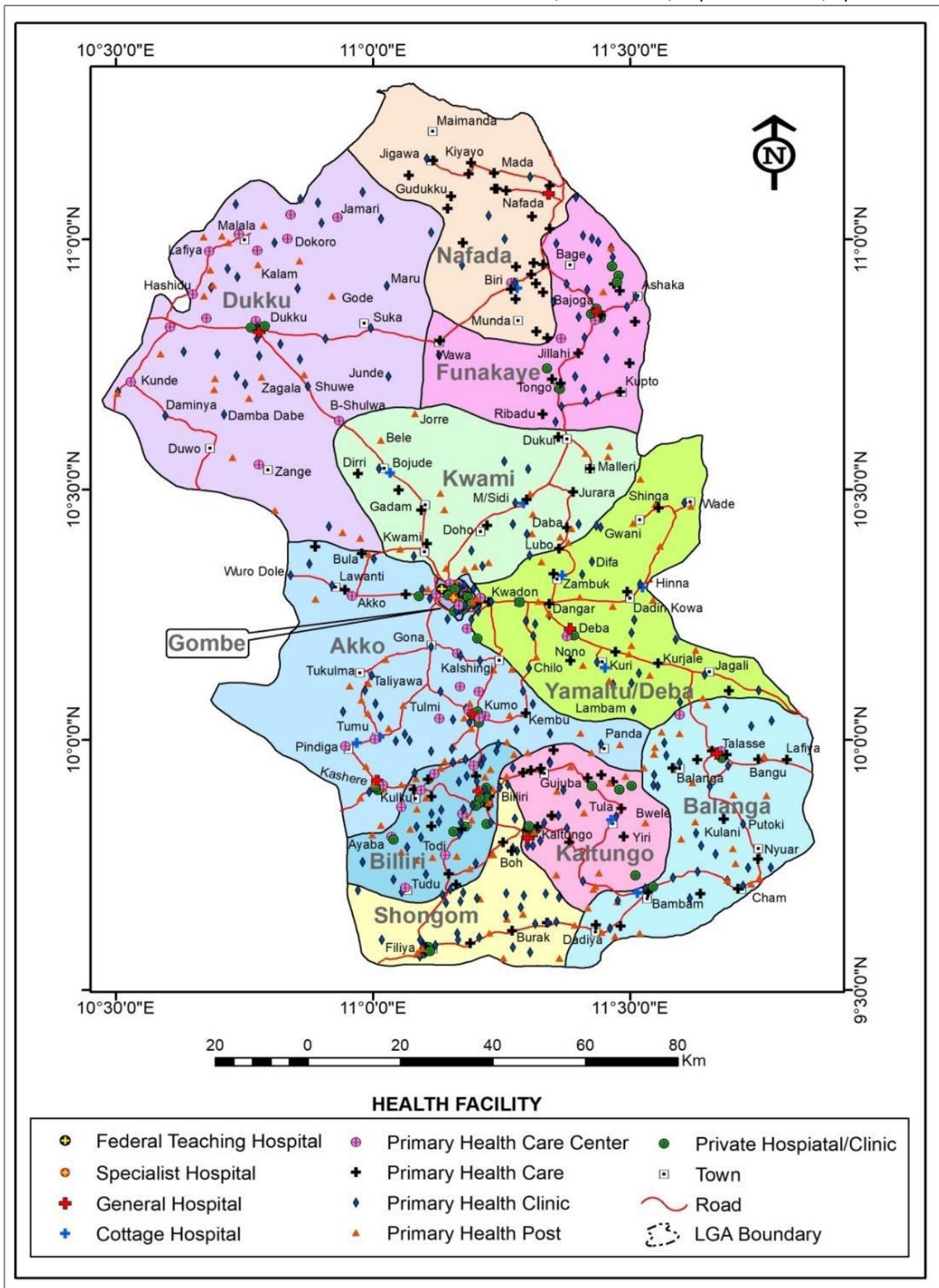
Figure 1: State Specialist Hospital Gombe's location in Nigeria's Gombe State and Gombe City (Yaro *et al.*, 2023).

Data Analysis: Poisson regression

Poisson regression analysis was employed for its suitability for count data, assuming equidispersion. This method allows for analyzing the relationship between typhoid incidence and weather variables, with adjustments for the pathogen's typical incubation period. Throughout five years, from 2015 to 2019, this method of statistical analysis was utilized to forecast the impact of variations in the mean daily measurements of humidity, wind speed, rainfall, and minimum and maximum temperatures on the incidences of typhoid fever (Dewan *et al.*, 2013a; Hayat and Higgins, 2014).
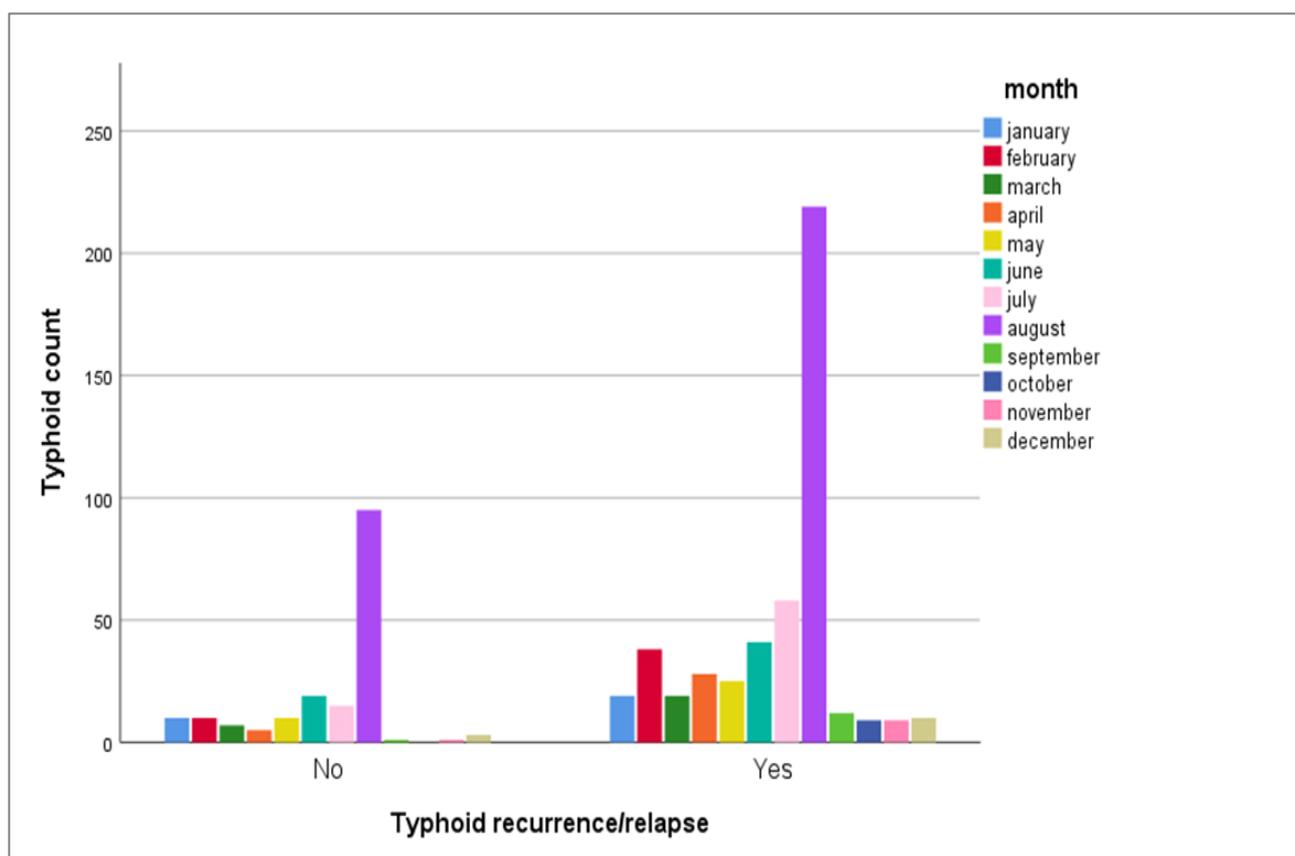
RESULTS

Typhoid Incidence, Recurrence, and Case Locations

The findings for calculating the typhoid incidence proportion showed that between 2015 and 2019, there were 9116 confirmed cases of typhoid per 100,000 people in the study area. The highest incidences were recorded in 2018, with 2555 cases per 100,000 people, followed by 2256 cases per 100,000 people in 2019, 1589 cases per 100,000 people in 2015, 1365 cases per 100,000 people in 2017, and the lowest number, 1351 cases per 100,000 people, in 2016.

There were 126 confirmed occurrences of typhoid relapse per 100,000 persons/year in the study region in 2019, according to the results for determining typhoid recurrence/relapse (Figure 2), which refers to a recurring occurrence of typhoid in an individual in the study area.

Between July and November 2019, there were both new cases and recurrences of typhoid (apart from Bajoga ward) from every ward in the metropolitan area in addition to Garko ward of Akko LGA, which is administratively not part of Gombe LGA but shares some suburbs with Gombe metropolis. These results were used to determine the location-based distribution of typhoid counts in the study area (Figure 3a).

Figure 3b illustrates the range of first-time cases—one in Herwa Gana ward to 58 in Shamaki ward—and recurrences—zero in Bajoga ward to 139 in Shamaki ward plus 147 in Garko ward. Typhoid incidences were concentrated in the Shamaki and lowest in the Herwa Gana wards, whereas recurrences were concentrated in the Garko and Shamaki wards and least in the Bajoga ward. The Shamaki and Bajoga wards generally had the most and the least cases, respectively.

Figure 2: Cases of typhoid recurrence or relapse in the Gombe municipality for the year 2019
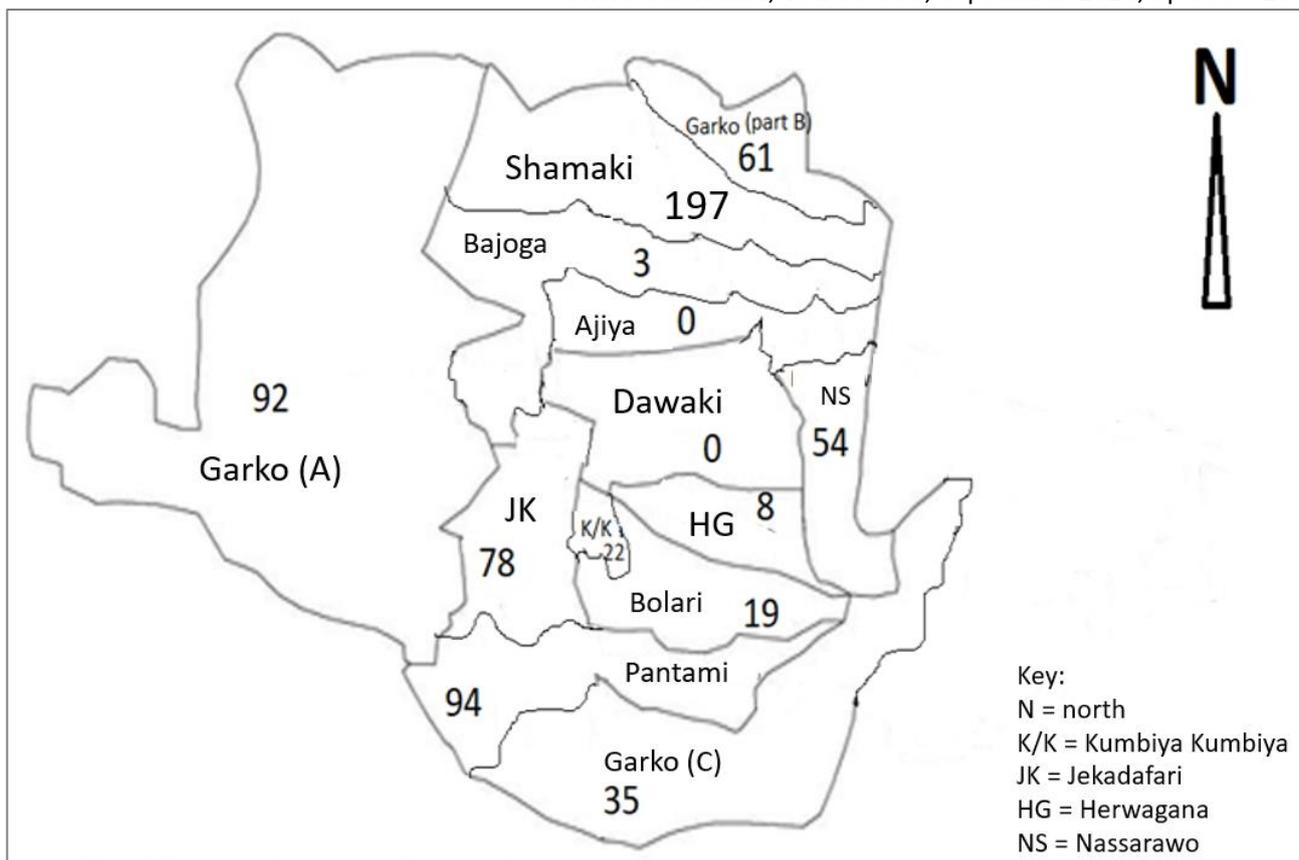
Figure 3a: A map of the Gombe metropolis that displays the results for the overall distribution of cases of typhoid throughout the city's administrative wards from July to November 2019
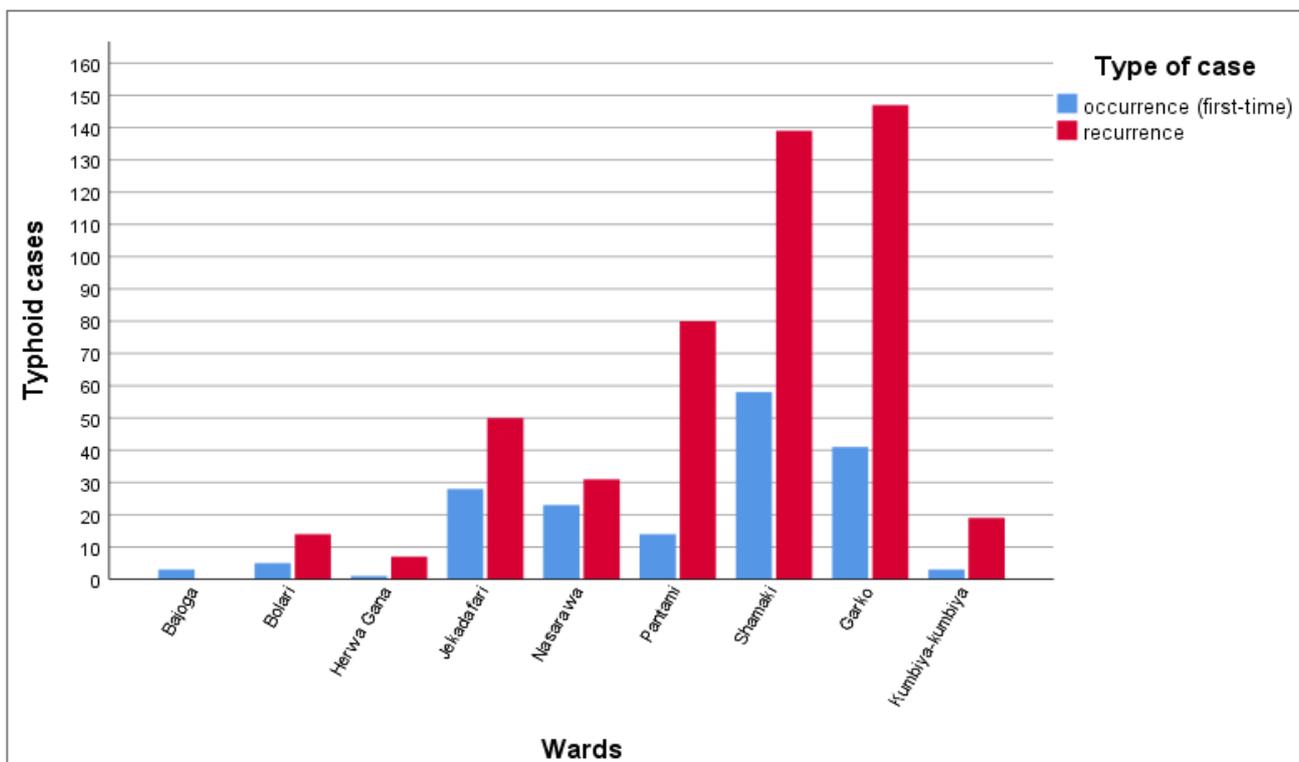
Figure 3b: Geographical incidence of new cases and relapses of typhoid fever in the administrative wards of Gombe city

Effect of Weather Conditions on Typhoid Incidences

The Poisson regression analysis (Table 1) revealed a significant association between increased minimum temperature and humidity with elevated typhoid incidences. This suggests that climatic conditions play a crucial role in the epidemiology of typhoid in Gombe Municipality.

A 1°C increase in the minimum temperature and a 5% increase in humidity were statistically significant predictors of the growth in typhoid incidents from 2015 to 2019. These conclusions were drawn Based on the Poisson regression analysis results. The minimum temperature had a significant association with an increase in typhoid occurrences of 1.080 (1.048 to 1.114) and $p <.01$, while the humidity had a significant association with an increase in typhoid occurrences of 1.041 (1.031 to 1.051) and $p <.01$.

The output of the analysis revealed that the model fit was good. Based on the calculated Pearson chi-square value/df of 1.011, which is close to 1, equidispersion (no overdispersion) is indicated. Based on the omnibus test's p-value of 0.000, which is less than the study's significance criterion of 0.010, the model was statistically significant.

Table 1: Parameter estimates from the Poisson regression analysis

Parameter	B	SE	99% Wald CI		Hypothesis test			Exp(B)	99% Wald CI for Exp(B)	
			Lower	Upper	Wald χ²	df	Sig.		Lower	Upper
Max temp	-0.006	0.0052	-0.019	0.008	1.204	1	0.273	0.994	0.981	1.008
Min temp	0.077	0.0117	0.047	0.108	43.381	1	0.000	1.080	1.048	1.114
Rain	0.014	0.0059	-0.001	0.030	6.018	1	0.014	1.015	0.999	1.030
Wind	-0.010	0.0109	-0.038	0.017	0.930	1	0.335	0.990	0.962	1.018
Humidity	0.040	0.0037	0.031	0.050	120.289	1	0.000	1.041	1.031	1.051
Atm. Pres.	0.000	0.0094	-0.024	0.024	0.002	1	0.968	1.000	0.977	1.025

DISCUSSION

September saw higher-than-average typhoid cases each year; this is believed to be because of the peak rainfall in the early August weeks and the subsequent increase in the lowest temperature in the October weeks. Both rainfall and temperature upsurge have been related to rising of typhoid fever infections (Dewan *et al.*, 2013b), and the 14 days typical incubation duration of the typhoid fever bacteria (Awofisayo-Okuyelu *et al.*, 2018) further justifies the lag in escalation of typhoid infections thought to have been contracted during the weeks of August or early in October. These findings agree with the reports of Morral-Puigmal *et al.* (2018) and Indhumathi and Kumar (2020), who had all reported how ascendant changes in weather circumstances amplified cases of typhoid infections.

The highest incidences are believed to result from a higher number of unvaccinated individuals and those drinking unhygienic water in those wards, and vice-versa for the locations with low cases, as discovered by Umar *et al.* (2022). These results are further supported by the widespread misconceptions and beliefs held by the local population in the research region that vaccinations are part of a plot to wipe out the population, render women infertile, or predispose children to fatal illnesses that will manifest themselves in adulthood. These misunderstandings and opinions have ensued in vaccine indecision and refusal, which have become the main obstructions to vaccination in numerous Nigerian communities, including Gombe (Cobos Muñoz *et al.*, 2015; WHO, 2020).

Drinking unclean water is suspected to be because of the deficiency of a steady source of potable water in the study area (Abdullahi and Abdu, 2018; Ishaku *et al.*, 2012), which has made individuals exploit locally erected wells, inappropriately sustained boreholes, commercially vended jerrycan water, water trucks, sachet water, and other impure water sources for drinking and routine activities, as described in preceding studies in Pakistan (Khan *et al.*, 2018) and Congo (Brainard *et al.*, 2018) where typhoid fever manifestations were all connected to use of impure water sources.

The high typhoid incidences could also be because Garko and Shamaki wards have larger landmass and are more populated than Herwa Gana and Bajoga wards (NPC, 2006), leading to congestion, which has been shown to elevate typhoid risks by uplifting the menaces of inter-human spread of the pathogen owing to added direct and close interaction amongst the congested people which increases the chances of these people consuming *S. typhi*-contaminated food/water or other consumable items which are among the major sources of the spread of this pathogen (Ayaz *et al.*, 2005; Sur *et al.*, 2007).

The interpretations of the Poisson regression analysis model fit are grounded on the efforts of Obubu *et al.* (2019), who described Pearson chi-square value/df of 1.0461 to reflect no overdispersion, and with the work of Riffenburgh and Gillen (2020), who described *p*-values less than significance level as indicators of statistical significance in Poisson regression analysis.

Our findings are consistent with studies from Dhaka, Spain, and China, which also reported increased typhoid

incidences with rising temperatures and humidity. In Spain, Morral-Puigmal *et al.* (2018) described how shifts in temperature influenced changes in the number of hospitalizations due to gastrointestinal ailments including typhoid between 1997 to 2013, while Indhumathi and Sathesh Kumar (2020) described how weather factors like temperature and humidity influenced changes in occurrences of transmittable ailments like typhoid fever between 2008 and 2012 using big data, while in China, Gao *et al.* (2022) reported that each 2°C rise in temperature resulted in 6% increase in typhoid cases between 2005 to 2013 in Taizhou city. This highlights the need for region-specific health interventions.

Furthermore, our findings are consistent with studies in Nigeria from Kaduna and Ilorin, which reported significant associations between climatic conditions and increased typhoid occurrences. In Kaduna, Suleiman *et al.* (2021) reported that increases in typhoid occurrences were significantly associated with upward trends of temperature and rainfall between 2014 to 2018, while in Ilorin, Ajibola *et al.* (2022) reported that typhoid occurrences were dependent on temperature, humidity, and sunshine, between 1999 to 2010. This highlights the need for nationwide health interventions against typhoid fever in Nigeria.

This association between weather conditions and typhoid occurrences could be because humans tend to perspire at a higher rate when the weather is hot or when they feel hot due to activities like exercising and, as such, tend to consume more water or cool beverages (Jingjing, 1999; Latzka and Montain, 1999) which is sourced from impure sources or prepared/handled unhygienically would increase the chances of contracting typhoid fever.

The significant associations between climatic conditions and the elevation of typhoid incidences reported in this study can inform early warning systems for timely provision or improvement of anti-typhoid health interventions such as health awareness campaigns, vaccinations, adequate and stable provision of water, sanitation, and hygiene, clearing of drainage systems, evacuation of sewage, and provision of adequate diagnostic and therapeutic resources. Such health interventions can be more efficiently delivered using the findings from this study which has generated the information that can be used to prioritize delivery of these health interventions. This will further improve the efficiency of resource utilization and timely delivery of such health interventions, thereby averting or reducing the incidences of typhoid in the area.

CONCLUSION

This 5-year epidemiological study has revealed high occurrences of typhoid and their significant association with temperature and humidity in Gombe Municipality. In addition, the study also revealed that more populated areas of Gombe Municipality had higher occurrences of the disease.

RECOMMENDATION

Given the significant impact of weather conditions on typhoid incidence, targeted health interventions, such as improved water sanitation during high-risk periods, are recommended to reduce the disease burden in Gombe Municipality. Future studies could incorporate additional data on demographic characteristics and environmental factors to better elucidate the complex interactions between weather, population dynamics, and typhoid transmission.

ACKNOWLEDGEMENT

REFERENCES

Abdullahi, A., and Abdu, A. (2018). Household Water Conditions in Gombe: A Profile of Water Scarcity in Nassarawo, Palliative and Mitigation Measures. *American Scientific Research Journal for Engineering, Technology, and Sciences*, *43*(1), 227–240.

Abdullahi, S., Abdulwahab, K., and Sadiq Abubakar, G. (2017). Gross Margin Analysis of Modern Groundnut Oil Extraction in Gombe Metropolis Gombe State, Nigeria. *World Journal of Agricultural Research*, *5*(2), 58–63. **[Crossref]**

Adabara, N. U., Ezugwu, B. U., Momojimoh, A., Madzu, A., Hashiimu, Z., and Damisa, D. (2012). The Prevalence and Antibiotic Susceptibility Pattern of *Salmonella* typhi among Patients Attending a Military Hospital in Minna, Nigeria. *Advances in Preventive Medicine*, *2012*, 1–4. **[Crossref]**

Adeyinka, S. Y., Wasiu, J., and Akintayo, C. O. (2014). Review on Prevalence of Water-borne Diseases in Nigeria. *Journal of Advancement in Medical and Life Sciences*, *1*, 5–7. **[Crossref]**

Agu, K., Nzegwu, M., and Obi, E. (2015). Prevalence, morbidity, and mortality patterns of typhoid ileal perforation as seen at the university of Nigeria teaching hospital Enugu Nigeria: An 8-year review. *World Journal of Surgery*, *38*(10), 2514–2518. **[Crossref]**

Ajibola, T. B., Olawepo, A. O., Nwabachili, S., and Yussuf A. H. (2022). Relationship among Some Prevalent Diseases and Changes in Weather at Ilorin over a Solar Cycle Period. *Ilorin Journal of Science, 9*(1), 1-19. **[Crossref]**

Andino, A., and Hanning, I. (2015). Salmonella enterica: Survival, Colonization, and Virulence Differences among Serovars. *The Scientific World Journal*, *2015*, 1–16. **[Crossref]**

Awofisayo-Okuyelu, A., McCarthy, N., Mgbakor, I., and Hall, I. (2018). Incubation period of typhoidal salmonellosis: a systematic review and meta-analysis of outbreaks and experimental studies occurring over the last century. *BMC Infectious Diseases*, *18*(1). **[Crossref]**

Ayaz, C., Loeb, M., Geyik, M. F., Acemoglu, H., Akalin, S., Hosoglu, S., and Celen, M. K. (2005). Risk factors for typhoid fever among adult patients in Diyarbakir, Turkey. *Epidemiology and Infection*, *134*(03), 612. [Crossref]

Brainard, J., D'hondt, R., Ali, E., Van den Bergh, R., De Weggheleire, A., Baudot, Y., Patigny, F., Lambert, V., Zachariah, R., Maes, P., Kuma-Kuma Kenge, D., and Hunter, P. R. (2018). Typhoid fever outbreak in the Democratic Republic of Congo: Case control and ecological study. *PLOS Neglected Tropical Diseases*, *12*(10), e0006795. [Crossref]

Cobos Muñoz, D., Monzón Llamas, L., and Bosch-Capblanch, X. (2015). Exposing concerns about vaccination in low- and middle-income countries: a systematic review. In *International Journal of Public Health* (Vol. 60, Issue 7, pp. 767–780). Birkhauser Verlag AG. [Crossref]

Crump, J. A. (2015). Building the case for wider use of typhoid vaccines. *Vaccine*, *33*(Suppl 3), C1. [Crossref]

Crump, J. A., Luby, S. P., and Mintz, E. D. (2004). The global burden of typhoid fever. In *Bulletin of the World Health Organization* (Vol. 82, Issue 5).

Dewan, A. M., Corner, R., Hashizume, M., and Ongee, E. T. (2013a). Typhoid Fever and Its Association with Environmental Factors in the Dhaka Metropolitan Area of Bangladesh: A Spatial and Time-Series Approach. *PLoS Neglected Tropical Diseases*, *7*(1), e1998. [Crossref]

Dewan, A. M., Corner, R., Hashizume, M., and Ongee, E. T. (2013b). Typhoid Fever and Its Association with Environmental Factors in the Dhaka Metropolitan Area of Bangladesh: A Spatial and Time-Series Approach. *PLoS Neglected Tropical Diseases*, *7*(1), 1998. [Crossref]

Gao, Q., Liu, Z., Xiang, J., Zhang, Y., Tong, M. X., Wang, S., Zhang, Y., Liu, Q., Jiang, B., & Bi, P. (2021). Impact of Temperature and Rainfall on Typhoid/Paratyphoid Fever in Taizhou, China: Effect Estimation and Vulnerable Group Identification. *The American journal of tropical medicine and hygiene*, *106*(2), 532–542. [Crossref]

Hati, S., and Dimari, G. (2011). Quality status of drinking water sources in Gombe Metropolis of Nigeria. *American Journal of Scientific and Industrial Research*, *2*(4), 537–542. [Crossref]

Hayat, M. J., and Higgins, M. (2014). Understanding poisson regression. *Journal of Nursing Education*, *53*(4), 207–215. [Crossref]

HFR (2019). Hospitals and Clinics, Nigeria Health Facility Registry. Federal Ministry of Health. Retrieved from: [Crossref]

Indhumathi, K., and Sathesh Kumar, K. (2020). A review on prediction of seasonal diseases based on climate change using big data. *Materials Today: Proceedings*. [Crossref]

Ishaku, H. T., Majid, M. R., and Johar, F. (2012). Rainwater Harvesting: An Alternative to Safe Water Supply in Nigerian Rural Communities. *Water Resources Management*, *26*(2), 295–305. [Crossref]

Jingjing, Q. (1999). *Fluoride in water: An overview.*

John, J., Van Aart, C. J. C., and Grassly, N. C. (2016). The Burden of Typhoid and Paratyphoid in India: Systematic Review and Meta-analysis. *PLoS Neglected Tropical Diseases*, *10*(4), 1–14. [Crossref]

Jombo, G. T., Msugh Mbaawuaga, E., Ahmed, U., Abba, P. O., and Tsor, J. O. (2019). Management of Typhoid Fever at a University Hospital in Sub-Saharan Africa: Challenges and Prospects. *International Journal of Health Sciences* and *Research*, *9*(1), 190.

Khan, K., Lu, Y., Saeed, M. A., Bilal, H., Sher, H., Khan, H., Ali, J., Wang, P., Uwizeyimana, H., Baninla, Y., Li, Q., Liu, Z., Nawab, J., Zhou, Y., Su, C., and Liang, R. (2018). Prevalent fecal contamination in drinking water resources and potential health risks in Swat, Pakistan. *Journal of Environmental Sciences (China)*, *72*, 1–12. [Crossref]

Latzka, W. A., and Montain, S. J. (1999). Water and electrolyte requirements for exercise. *Clinics in Sports Medicine*, *18*(3), 513–524. [Crossref]

Lawal, J., Jajere, S., Mustapha, M., Bello, A., Wakil, Y., Geidam, Y., Ibrahim, U., and Gulani, I. (2015). Prevalence of Newcastle Disease in Gombe, Northeastern Nigeria: A Ten-Year Retrospective Study (2004 – 2013). *British Microbiology Research Journal*, *6*(6), 367–375. [Crossref]

Masuet-Aumatell, C., and Atouguia, J. (2021). Typhoid fever infection – Antibiotic resistance and vaccination strategies: A narrative review. In *Travel Medicine and Infectious Disease* (Vol. 40, p. 101946). Elsevier BV. [Crossref]

Mawazo, A., Bwire, G. M., and Matee, M. I. N. (2019). Performance of Widal test and stool culture in the diagnosis of typhoid fever among suspected patients in Dar es Salaam, Tanzania. *BMC Research Notes*, *12*(1). [Crossref]

Mike, I., Maori, L., Adamu, A., Gushit, S., Maryam, L., Florence, G., Abdullfattah, S., and Shittu, N. (2017). Prevalence of Malaria and Typhoid Co-Infections among Patients who Attended State Specialist Hospital Gombe from May to August 2015 for Malaria and Widal Tests. *Greener Journal of Epidemiology and Public Health, 5*(5), 037-043. [Crossref]

Morral-Puigmal, C., Martínez-Solanas, È., Villanueva, C. M., and Basagaña, X. (2018). Weather and gastrointestinal disease in Spain: A retrospective time series regression study. *Environment International*, *121*, 649–657. [Crossref]

NPC. (2006). *2006 PHC Priority Tables*. National Population Commission. citypopulation.de

Obubu, M., Afeez Mayowa, B., and Chukwudike, N. (2019). Poisson Regression Modeling of Pregnancy Related Death in Oyo State, Nigeria. *Asian Journal of Pregnancy and Childbirth*, *2*(2), 1–5.

Odikamnoro, O. O., Ikeh, I. M., Okoh, F. N., Ebiriekwe, S. C., Nnadozie, I. A., Nkwuda, J. O., and Asobie, G. C. (2017). Incidence of Malaria/Typhoid Co-Infection Among Adult Population in Unwana Community, Afikpo North Local Government Area, Ebonyi State, Southeastern Nigeria. *African Journal of Infectious Diseases*, *12*(1), 33–38. **[Crossref]**

Population Stat. (2021). *Gombe, Nigeria Population (2021) - Population Stat*. Gombe, Nigeria Population. https://populationstat.com/nigeria/gombe

Ranjeeth, S., Latchoumi, T. P., and Paul, P. V. (2020). Role of gender on academic performance based on different parameters: Data from secondary school education. *Data in Brief*, *29*, 105257. **[Crossref]**

Riffenburgh, R. H., and Gillen, D. L. (2020). Poisson regression for count outcomes. In *Statistics in Medicine* (pp. 459–475). Elsevier. **[Crossref]**

Siddiqui, F. J., Rabbani, F., Hasan, R., Nizami, S. Q., and Bhutta, Z. A. (2006). Typhoid fever in children: some epidemiological considerations from Karachi, Pakistan. *International Journal of Infectious Diseases*, *10*(3), 215–222. **[Crossref]**

Suleiman, M., Lawrance, E., and Muhammed, H. B. (2021). The Influence of Some Weather Elements on The Occurrence of Malaria and Typhoid in Tudun Wada Kaduna South L.G.A. Kaduna State. *International Journal of Environmental Design & Construction Management, 20*(4), 22-38.

Sur, D., Ali, M., Von Seidlein, L., Manna, B., Deen, J. L., Acosta, C. J., Clemens, J. D., and Bhattacharya, S. K. (2007). Comparisons of predictors for typhoid and paratyphoid fever in Kolkata, India. *BMC Public Health*, *7*, 1–10. **[Crossref]**

Techasaensiri, C., Radhakrishnan, A., Als, D., and Thisyakorn, U. (2018). Typhoidal salmonella trends in Thailand. *American Journal of Tropical Medicine and Hygiene*, *99*(3), 64–71. **[Crossref]**

Umar, A. T., Shohaimi, S., Amin-Nordin, S., Nadzir, M. N. H. M., Ab Rahman, A., and Salari, N. (2022). Epidemiology and Risk Factors for Typhoid Fever in Gombe Metropolis, Gombe State, Nigeria. *Malaysian Journal of Public Health Medicine, 22*(2), 110-121.

WHO. (2020). *Nigeria consolidates efforts to curtail vaccine hesitancy | WHO | Regional Office for Africa*. WHO Africa. https://www.afro.who.int/news/nigeria-consolidates-efforts-curtail-vaccine-hesitancy

Wilson, N., Blakely, T., Foster, R. H., Hadorn, D., and Vos, T. (2012). Prioritizing risk factors to identify preventive interventions for economic assessment. *Bulletin of the World Health Organization*, *90*(2), 88–96. **[Crossref]**

Wong, V. K., Holt, K. E., Okoro, C., Baker, S., Pickard, D. J., Marks, F., Page, A. J., Olanipekun, G., Munir, H., Alter, R., Fey, P. D., Feasey, N. A., Weill, F.-X., Le Hello, S., Hart, P. J., Kariuki, S., Breiman, R. F., Gordon, M. A., Heyderman, R. S., … Obaro, S. (2016). Molecular Surveillance Identifies Multiple Transmissions of Typhoid in West Africa. *PLOS Neglected Tropical Diseases*, *10*(9), e0004781. **[Crossref]**

Yaro, H., Shaba, H. A., Jibril, A. B., Mai, J. D., Waziri, A. I., Atang, I., Samaila, A. S., Nansak, N. E., Nathan, L., Abdulkadir, A., Abraham, G. C., Ibrahim, M., and Haruna, S. (2023). Identification, Characterization and Mapping of Health Facilities Gombe State Nigeria. *International Journal of Innovative Science and Research Technology, 8*(5), 3204-3216.