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

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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 inconstant 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).

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

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
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.

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
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 \( p < .01 \).

<table>
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<th>Parameter</th>
<th>B</th>
<th>SE</th>
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<th>Hypothesis test</th>
<th>Exp(B)</th>
<th>99% Wald CI for Exp(B)</th>
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<td>-0.019 0.008</td>
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<td>Min temp</td>
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<td>0.0117</td>
<td>0.047 0.108</td>
<td>43.381 1 0.000 1.080 1.048 1.114</td>
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<tr>
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<td>0.0059</td>
<td>-0.001 0.030</td>
<td>6.018 1 0.014 1.015 0.999 1.030</td>
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<tr>
<td>Wind</td>
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<td>0.0109</td>
<td>-0.038 0.017</td>
<td>0.930 1 0.335 0.990 0.962 1.018</td>
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<tr>
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<td>0.031 0.050</td>
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</table>

**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-Pugmal 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 interpersonal 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 occurrences of 1.041 (1.031 to 1.051) and \( p < .01 \).
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 Satheesh 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.

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