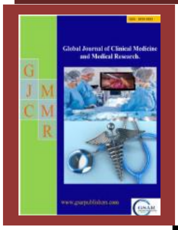

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Epidemiological Overview and Predictive Modelling of Cholera Outbreak in Abia State, Nigeria, January 2021-June 2023

BY

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Abstract

Background: *Cholera remains a public health threat in Nigeria. In Abia State, southeast Nigeria, cholera outbreaks are common with limited data coverage. This study is a descriptive analysis of cholera outbreaks across various local government areas in the state between 2021 and 2023, to identify predictors of cholera incidence and mortality.*

Methods: *A retrospective analysis of line lists obtained from 12 of 17 LGAs was conducted. The attack and case fatality rates were calculated, and the outbreaks were described by time, place, age, and gender using specified statistics.*

Results: *12 of 17 LGAs in Abia State experienced outbreaks between January 2021 and June 2023; in that timeframe, 354 cases and 13 deaths were recorded. Aba South and Umuahia North, the most industrial towns in the state experienced the highest incidences of the disease over the study period. The highest AR was recorded in Umuahia North (58.70 per 100,000). Inadequate sanitation infrastructure is a major facilitator of cholera outbreaks in Abia State.*

Conclusion: *This study identified the key epidemiological factors contributing to cholera outbreaks in Abia State, Nigeria, between 2021 and 2023. The results highlight the immediate necessity for enhanced public health measures, with a particular emphasis on the improvement of sanitation practices, especially in densely populated urban regions. Furthermore, the development of a predictive model using linear regression has enabled the anticipation of future cholera incidence in Abia State.*

Keywords: *Abia, Cholera, Epidemic Period, Nigeria, Outbreak*

INTRODUCTION

Cholera is a fast dehydrating, watery diarrheal sickness that is caused by the highly transmittable bacteria vibrio cholerae (serotypes O1 and, to a much lesser extent, O139). (Adagbada, et al., 2012). While Vibrio cholerae has an incubation period of 2 hours to 5 days, it remains present in an infected person's faeces for 1–10 days after infection. It is then shed back into the environment, potentially infecting other people. Most infected people remain asymptomatic. The majority of those who experience symptoms do so mildly or moderately, while a minority experience severe dehydration and acute watery diarrhoea (Onwe, et al., 2018) Cholera, when left unattended, can have a case fatality rate (CFR) of about 30-50%. However, when promptly arrested with adequate rehydration therapy, the CFR is reduced to as low as 1% (Elimian et al., 2019).

Cholera in Nigeria

Cholera has been recognized as a significant public health burden, disproportionately affecting the poor and most vulnerable people in low and middle-income countries like Nigeria (Owoeye et al., 2018). Several socioeconomic and environmental determinants of cholera outbreaks in Nigeria include poor living conditions, lack of potable water, sanitation, and hygiene (WASH) services; poor waste management and overcrowding in urban areas, flooding, and extreme temperatures due to climate change, and human displacement due to conflict and insurgency, (Leckebusch et al., 2015; Olaitan, et al., 2022).

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In 2011, the Federal Ministry of Health reported 37,289 cases with 1,434 fatalities between January and October 2010, while 22,797 cases, 728 fatalities, and a case-fatality rate of 3.2% were recorded in 2011. In 2018, the Nigeria Centre for Disease Control (NCDC) reported 42,466 suspected cases from January to October, including 830 fatalities and a case fatality rate of 1.95% in 20 out of 36 states in the country. In 2021, 65,145 suspected cases including 2,141 deaths were reported from 23 states only (Nigeria Centre for Disease Control (NCDC), 2021; Olaitan, et al., 2022). These constant outbreaks with increasing morbidity and mortality numbers are indicative of a lack of adequate prevention and control measures, and because cholera is an underreported disease, the true burden may be much higher than indicated (Centres for Disease and Prevention (CDC), 2022).

The substantial medical expenses for treating cholera in Nigeria pose a significant burden on the economy. Although an additional effective strategy to contain cholera outbreaks, oral cholera vaccines (OCV) are only occasionally employed as a cholera control mechanism in Nigeria. However, in addition to providing sanitary conditions, clean portable water, and improving waste management, WHO reports that OCVs are effective in the proactive prevention and control of cholera outbreaks (Ali et al., 2012). Reporting on the first-ever recorded use of OCVs in Nigeria, Balami et al., (2020) highlighted the role played by using OCVs in conjunction with WASH services in ending the 2017 cholera outbreak in Internally Displaced Persons (IDPs) camps across various local government areas (LGAs) in Bornu State, subsequently recommending OCV use, as well as services allowing for the feasibility of OCV use in proactively controlling future outbreaks.

STUDY SETTING

This is a retrospective study of secondary research data from 11th January 2021 to 9th June 2023. Of the 17 LGAs in Abia State, 12 LGAs reported cholera cases over the specified timelines. The affected LGAs and their corresponding senatorial zones are as follows: Arochukwu, Bende, Ohafia, Umu-Nneochi and Isuikwuato (Abia North); Isiala-Ngwa North, Umuahia North and Umuahia South (Abia Central); Aba South, Ugwunabo and Ukwa East (Abia South).

Notification of the Most Recent Outbreak (January 2023)

A surge in reported diarrhoea cases in Amaogwugwu community of Umuahia North Local Government Area of Abia State in January 2023 raised suspicion of cholera, prompting a report to the Abia State Public Health Emergency Operation Centre (ABPHEOC) by the LGA Disease Surveillance Notification Officer (DSNO). This was then followed by an epidemiological investigation by a rapid response team, which involved the use of rapid diagnostic tests and isolation of Vibrio cholerae O1 or O139 from stool samples in accordance with the NCDC guidelines (NCDC, 2017). Primary health and secondary health units in the affected local government areas relied on rapid diagnostic testing in suspected cases and some samples were sent to the NCDC reference laboratory in Abuja for confirmation. Using pre-defined line lists, all suspected cases were collated and reported weekly to the DSNO who then transmitted these data to the State Epidemiologist for aggregation and further transmission to the Surveillance and Epidemiology Department (SED), NCDC, in Abuja for further statistical analysis.

At the onset of the 2023 cholera outbreak in Abia state, there were no published records on the prevalence or factors associated with previous cholera outbreaks in the state. While epidemiologic surveillance and availability of surveillance data are major components of the surveillance loop and facilitate essential public health response, Nigeria produces very limited publicly available surveillance data largely due to the underreporting of cases (Adagbada et al., 2012). Understanding the factors influencing cholera spread in Abia State is essential in preventing future outbreaks through appropriate public health interventions in the state. The 2023 cholera outbreak offers a chance to analyse the epidemiology of cholera in Abia State to establish the evidence-based knowledge needed for comprehensive public health planning and interventions to help in the mitigation of future outbreaks and inform efficient resource allocation.

This study is a descriptive analysis of secondary surveillance data on cholera outbreaks in Abia State between January 2021 and June 2023 in terms of person, place, and time.

Table 1. Definition of Key Variables

Variables	Definitions
Age:	Age was defined in years and classed as a categorical variable.
Season:	The rainy season was defined from April to October and the dry season from November to March.
Epidemic Period:	Period of rapid disease (cholera) spread through a population, which in this study is between January 2021 and June 2023
Attack Rate (AR):	AR was defined as the ratio of cholera cases in a defined area (e.g., LGA) to the estimated population of that area. AR for each reporting LGA was calculated using the estimated population of 2023, based on a 1.9% projected growth rate from the 2006 national census results; the values were multiplied by 100,000 for easier interpretation of small values.
Case Fatality Rate (CFR):	Expressed in percentage, CFR was defined as the ratio of individuals classified as cholera cases who died to all individuals classified as cholera cases, both living and dead.

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Table 2. Baseline characteristics of cases during the 2021 - 2023 cholera outbreaks in Abia State (N = 354).

LGA	Cases	Deaths	Estimated Population (2021-2023)	Attack Rate (AR)/ 100,000 population	Case Fatality Rate (CFR) (%)
Aba South	78	0	559,485	13.9	0.0
Umuahia North	78	4	132,871	58.7	5.1
Umu-Nneochi	65	4	216,385	30.0	6.2
Ugwunabo	56	3	128,977	43.4	5.4
Ohafia	23	1	309,804	7.4	4.4
Ukwa East	17	0	110,702	15.4	0.0
Bende	10	1	254,260	3.9	0.0
Arochukwu	9	0	255,842	3.5	0.0
Umuahia South	7	0	182,912	3.8	0.0
Osisioma Ngwa	6	0	289,914	2.1	0.0
Isiala-Ngwa North	3	0	202,929	1.5	0.0
Isuikwuato	2	0	200,244	1.0	0.0

METHODS

Study Population and Definition of Key Variables

The population under study consists of individuals resident in the LGAs who were suspected of being cholera cases during the specified outbreak periods (January 2021- December 2021, January 2022 – June 2022, and January 2023- June 2023). As this analysis is being conducted in an outbreak setting endemic to cholera, the National Technical Guidelines of the Integrated Disease Surveillance and Response (IDSR) were followed in defining a cholera case. We, therefore, described a cholera case as any individual presenting with acute watery diarrhoea with or without vomiting during the outbreak periods (FMOH-NCDC, 2019, CDC, 2022).

Data Source and Management

In this study, the main data source utilized was secondary data extracted in CSV format from the Surveillance Outbreak Response Management and Analysis System (SORMAS). SORMAS serves as a robust repository for epidemiological data developed to support the surveillance, monitoring, and management of infectious diseases, making it a valuable resource for this research. To carry out data preparation, exploration, and analysis, Python version 3.9.7 was employed within a Jupyter Notebook environment. Python's versatility and data manipulation capabilities were harnessed through its Pandas library, which facilitated efficient data cleaning, transformation, and exploration. This initial phase of the research ensured that the dataset was properly structured and suitable for subsequent statistical analysis, enhancing the reliability and validity of our findings.

Prior to the final analysis, all identifiers, including names, addresses, and phone numbers of patients, were removed in accordance with NCDC ethical principles on confidentiality and anonymity.

Statistical Analyses

Using appropriate statistical summaries, such as frequency and percentage for binary/categorical variables and mean and standard deviation for normally distributed continuous variables, we first conducted an exploratory data analysis of the baseline characteristics of the study population. The Attack Rate (AR) and Case Fatality Rate (CFR), which were examined in relation to significant research variables, were the main outcomes of interest. We used the conventional person, place, and time analytic paradigm to fully explain the cholera outbreak. Statistical tests, including chi-square tests and p-value with statistical significance determined at alpha = 0.05, were employed to assess the statistical significance of differences In Attack Rates (AR) and Case Fatality Rates (CFR) between regions. Furthermore, Regression analysis was used to identify predictors of cholera incidence and mortality. Based on historical (Jan 2021 - Jun 2023) data, Linear Regression, a Machine Learning technique, was utilized to forecast Cholera incidence and predict case fatality rate for the

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next months in 2023. The next sections of this research article concentrate on additional information and conclusions from these analyses.

Table 3. Baseline characteristics of cases during the 2021 - 2023 cholera outbreaks in Abia State (N= 354).

Baseline Characteristics	Frequency (%)
Sociodemographic Characteristics	
Gender	
• Male	169 (47.7)
• Female	185 (52.3)
Median age, years	34 (1 - 78)
Age, years	
• 0 – 9	163 (46)
• 10 – 19	44 (12.4)
• 20 – 29	51 (14.4)
• 30 – 39	37 (10.5)
• 40 – 49	27 (7.6)
• 50 – 59	13 (3.7)
• ≥60	19 (5.4)
Senatorial zones	
• Abia North	109 (30.8)
• Abia Central	88 (24.9)
• Abia South	151 (42.7)
Epidemic period	
2021	
• Quarter 1 (Jan)	2 (0.6%)
• Quarter 2 (Apr)	2 (0.6%)
• Quarter 3 (Aug - Sept)	87 (24.6%)
• Quarter 4 (Oct – Dec)	29 (8.2%)
2022	
• Quarter 1 (Jan – Mar)	63 (17.8)
• Quarter 2 (Apr – May)	25 (7%)
• Quarter 3 (Jul - Aug)	3 (0.8%)
• Quarter 4 (Nov)	2 (0.6%)
2023	
• Quarter 1 (Jan – Mar)	107 (30.2%)
• Quarter 2 (Apr – Jun)	34 (9.6%)
Season	
• Rainy	169 (48%)
• Dry	185 (52%)
Culture Outcome	
• Positive	25 (7.1)
• Negative	63 (17.8)
• Pending	266 (75.1)
Clinical Outcome	
• Alive	341 (96.3%)
• Dead	13 (3.7%)

RESULTS

Twelve out of seventeen LGAs in Abia State experienced cholera outbreaks between January 2021 and June 2023, resulting in 354 cases and 13 deaths recorded through the outbreak periods under study. Notably, the epidemic period was characterised by three peaks (Figure 1). The first peak in September 2021 was marked by 83 cases and 2 deaths, primarily concentrated in Aba South (49.4%), Ugwunagbo (45.9%), and Osisioma Ngwa (4.7%). The second peak with 39 cases and 1 death appeared in February 2022. Umu-Nneochi (47.5%) had the highest burden, followed by Aba South (22.5%), Ukwa East (20%), and Ugwunagbo & Arochukwu (5%). The final peak in the epidemic period, in January 2023, recorded 57 cases and 3 deaths, with Umuahia North (94.9%) contributing significantly, while Aba South and Bende accounted for 3.4% and 1.7%, respectively.

Table 4. Results based on age distribution.

Age Group (yrs)	Cases with documented Results		
	Positive	**Negative**	**Pending**
0-9	10	35	118
10-19	5	3	36
20-29	0	9	42
30-39	2	2	33
40-49	6	5	16
50-59	0	6	7
60-69	1	2	8
70-79	1	1	6
Total	**25**	**63**	**266**

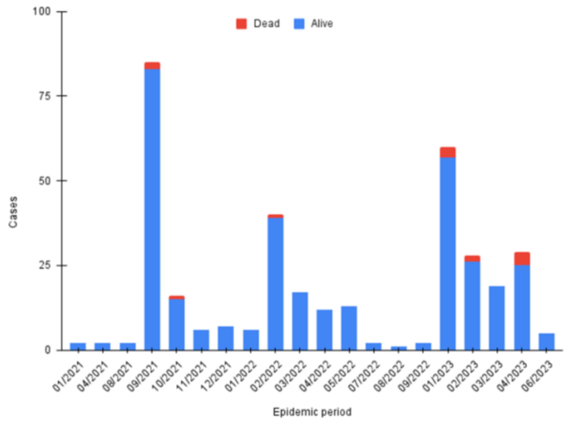

Figure 1. Reported cholera cases and deaths, January 2021 - June 2023.

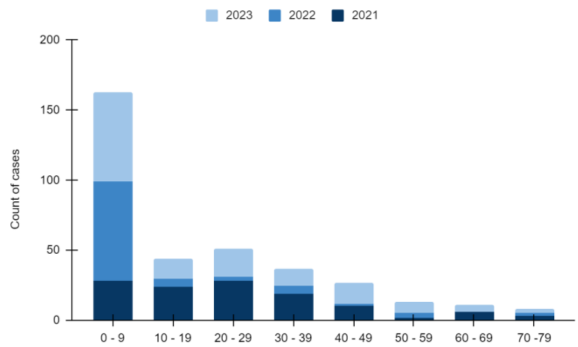

Figure 2. Age Distribution

Geographically, Aba South and Umuahia North LGAs reported the highest incidence of cholera cases (Table 2). Interestingly, while there appeared to be minimal disparity in seasonality with respect to case numbers, a higher proportion of cases surfaced during the dry season (52%) as opposed to

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the rainy season (48%). Additionally, mortality rates were elevated during the rainy season (54%) compared to the dry season (46%).

A comprehensive demographic analysis revealed that the median age of cholera cases was 34 years, with the age group of 0 to 9 years being the most affected (Figure 2). Additionally, a slight gender disparity was observed, with females accounting for 52.3% of cases.

In terms of regional trends, most cholera cases were concentrated in LGAs within the Abia South senatorial zone. However, it is noteworthy that LGAs in the Abia North senatorial zone consistently reported cases more frequently than other zones. The two most urbanized LGAs in the state, Aba South and Umuahia North, collectively represented a significant portion of the reported cases, totaling 44.1% of the overall count. Attack rates (AR) and case fatality rates (CFR) provided further insights into the impact of the outbreaks. The total AR for the entire study period stood at 184.7 per 100,000 population (Table 2). Umuahia North LGA exhibited a significantly higher AR of 58.70 per 100,000 population, followed by Umu-Nneochi LGA with 30.0 per 100,000 population. Conversely, Isuikwuato and Isiala-Ngwa North LGAs displayed notably lower ARs at 1.0 and 1.5 per 100,000 population, respectively. The overall CFR for cholera during the study period was recorded at 3.7%, with the CFR in 2021 at 2.5%, dipping to 1.1% in 2022 and making a sharp rise in 2023 to 6.5%. 266 recorded cases lacked complete data, with the results section marked as 'Pending'.

Figure 2a. Spatial Distribution of Cholera- Attack Rate

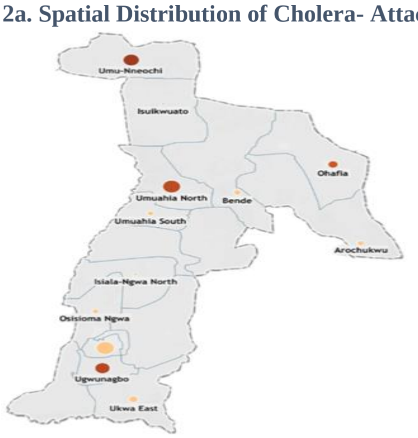

Figure 3b. Spatial Distribution of Cholera - Case Fatality Rate

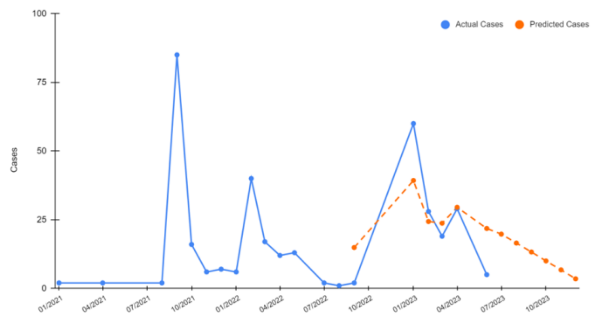

Figure 3. Predicted Cases

Application of Machine Learning for Prediction

In our pursuit to gain deeper insights into the dynamics of cholera outbreaks in Abia State, we used machine learning techniques, specifically, Linear Regression to develop a predictive model that could forecast the number of cholera cases for the subsequent months in 2023 (July to December). This approach allowed us to explore the potential impact of various factors on the incidence of cholera and enhance our ability to make informed decisions for public health interventions.

Linear Regression Model

Linear Regression is a fundamental machine learning algorithm that seeks to establish a linear relationship between one or more independent variables (predictors) and a dependent variable (the target). Regression techniques belong to inferential statistics and can be used when the outcome of interest is numeric (Marco, 2023).

Our Linear Regression model was trained using historical cholera data collected between January 2021 and June 2023. In this model, the epidemic period was the independent variable (predictor), and the number of cholera cases was the dependent variable (the target).

The evaluation of our Linear Regression model was conducted using key metrics: Mean Squared Error (MSE) quantifying prediction accuracy (MSE = 77.56), Root Mean Squared Error (RMSE) measuring prediction precision (RMSE ≈ 9.57), and R-squared (R^2) indicating model fit to the data ($R^2 = 0.65$). A lower MSE signifies close alignment with observed data, a lower RMSE implies precise predictions and a higher R^2 suggests a better model fit, collectively demonstrating the model's effectiveness in forecasting cholera cases.

DISCUSSION

The study analysed cholera outbreaks across twelve of the seventeen LGAs in Abia State Southeast Nigeria, between January 2021 to June 2023. The first suspected cases in 2021 were reported in the Abia Central senatorial zone (Umuahia North LGA). The 2021 outbreak was then confirmed in Abia South senatorial zone (Ugwunagbo LGA). The 2022 cholera outbreak was initially suspected in Ohafia LGA and confirmed in Umu-Nneochi, both in Abia North senatorial zone. The 2023 outbreak was also suspected and confirmed in Abia South zone (Aba South). Each senatorial zone in Abia was affected by cholera outbreaks between 2021 and 2023.

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This is indicative of the inadequate sanitation infrastructure and limited access to water and healthcare facilities and resources in the state, as well as socioeconomic challenges facilitating these issues, and encouraging continuous outbreaks in the state (Fagbamila, 2023).

Aba South and Umuahia North both experience the highest burden of cholera cases.

Aba South is home to Aba, one of the most densely populated cities in Abia State. It is the industrial and commercial hub of the state with an estimated 236,703 tonnes of waste generated monthly (Ezechi et al., 2017; Idu et al., 2023). Due to overpopulation, indiscriminate waste disposal practices at unapproved dumpsites, roadsides, or water sources like streams and rivers; and inadequate waste management and handling facilities, Aba is recorded as one of the dirtiest cities in Nigeria (Kilani et al., 2019). Umuahia North, the capital city is also densely populated and faces similar waste management problems like Aba (Onwughara et al., 2013). Accumulated waste leads to widespread pollution of land, air, and water, including contamination of groundwater. This constant threat endangers residents due to compromised main water sources such as rivers, streams, and boreholes (Agwu et al., 2013). The high cholera burden evidenced in these two cities through the number of cases reported is reflective of the unsanitary conditions that have been shown to facilitate cholera outbreaks in Nigeria (Stanley et al., 2014; Leckebusch et al., 2015; Olaitan et al., 2022).

In this study, there were more cholera cases in the dry season (52%) than in the rainy season (48%), with more deaths occurring during the rainy season (54%). Drawing from epidemiological observations of multiple cholera outbreaks in Nigeria, it has been noted that the occurrence of these outbreaks varies across seasons and is not consistent with regard to age and gender demographics (Idoga et al., 2019). Nigeria has two main seasons: rainy and dry seasons. The rainy season is characterised by flooding, which results in elevated water levels. This condition is conducive to the proliferation and dissemination of bacteria and other vectors from the waste and sewage they carry, contributing to the seasonality of cholera outbreaks (Adelakan, 2009). The dry season is characterised by drought and limited access to portable or clean drinking water, especially in lower-income socioeconomic groups (Fagbamila et al., 2023).

In terms of age distribution, the age group affected most across the study period was children between 0 to 9 years old, with this age group alone accounting for 38% of the mortality cases. Cholera and other diarrheal diseases are the primary cause of morbidity and secondary cause of mortality in children 0 to 5 years old (Bryce et al., 2005). The dynamism of the age groups most affected by cholera outbreaks in Nigeria is noteworthy. Where this study and that by Dan-Nwafor et al., 2019, show children to be most affected by the disease, others including Shittu et al. (2010) and Ibrahim et al. (2017) indicate the age range most affected by cholera extends into adulthood.

Regarding the gender distribution, in this study, more females than males were affected by cholera, moreover, fatalities were higher in males than females. This aligns with prior research indicating a higher incidence of infection among females and higher mortality in males (Ibrahim et al., 2017). Men and women have an equal risk of being infected by vibrio cholerae, but the chances of women and girls contracting the disease might be exacerbated by their involvement in domestic tasks like caring for the sick, handling contaminated water, and preparing infected food (Burbur et al., 2017; Fagbamila et al., 2023). Like the distribution of age and seasonality in Nigeria, the gender distribution is also dynamic in the sense that in some cases women are more affected than men, and in others, men are more affected than women by cholera (Idoga et al., 2019).

The AR and CFR were each calculated cumulatively between 2021 and 2023 given the sparse amount of data available. The AR is a measure of the frequency of new cholera cases within the population during the specified period under study (Ibrahim et al., 2017). The overall AR for all twelve LGAs over the study period is 184.7/100,000 population. In Umuahia North, the AR is highest, indicating significant cholera incidence in the densely populated state capital. CFR is the proportion of reported cholera cases resulting in death divided by the total number of cholera cases (Kim et al., 2020). Between 2021 and 2023, the CFRs calculated surpass the WHO recommended threshold of ≤1 in cholera-endemic areas (Ibrahim et al., 2017). The 2023 CFR of 6.5% is high and indicative of challenges in the Abia state healthcare system, and access to and delivery of healthcare. Nevertheless, we believe that the variability in how cholera cases are defined in Nigeria, coupled with a high number of cases with incomplete information may impact the accuracy of the CFR estimation in our present study. Therefore, it is essential to interpret this result with caution.

Strengths and Limitations

SORMAS records showed that RDT testing confirming cholera infection was performed on only 4.5% of suspected cases between 2021 and 2023 in Abia state. This record is notably inadequate and highlights the need for improvement in the number of suspected cases being RDT tested to effectively ascertain epidemiological determinants of cholera in the state. The amount of data recorded over the three-year study period on cholera is limited, and the sum of incomplete data (results recorded as 'Pending') exceeds the complete data available highlighting some of the challenges encountered by developing nations in the context of efficient disease surveillance and reporting (Dalhat et al., 2014). There is a need for an efficient surveillance system, equipped to report cholera cases promptly and adequately in Abia state, thereby facilitating effective response and curtailing the spread of the disease during outbreaks.

Considering the challenges posed by the limited availability of comprehensive data in the Abia state cholera surveillance system, the introduction of our predictive model plays a pivotal role in enhancing our understanding of cholera dynamics. It has also enabled the anticipation of future

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cholera incidence in Abia State. These predicted values serve as valuable key performance indicators (KPIs) for monitoring the effectiveness of implemented interventions and guiding future public health strategies. By tracking the deviation between predicted and actual cholera cases, policymakers can assess the impact of their efforts and make timely adjustments to optimize resource allocation and intervention effectiveness. The stark reality of RDT testing confirming cholera infection in only 4.5% of suspected cases between 2021 and 2023 underscores the urgency to improve the efficiency of cholera data collection and surveillance efforts. Our model not only serves as a valuable tool for forecasting cholera cases but also sheds light on the factors contributing to its spread. By leveraging machine learning techniques, we have unveiled temporal patterns, identified high-risk regions, and captured the interplay between various factors and cholera incidence. However, it is essential to acknowledge the limitations of our model. While our model accounts for normal variations in cholera occurrence, we recognize that it may not capture all the intricacies of this naturally occurring phenomenon. Variations, in this case, are inherent to cholera's complex epidemiology, and our model provides insights within the boundaries of available data.

Additionally, the case definition used in this study differs from that used by WHO regarding age criteria. This study defines cases as any individuals meeting the case definition criteria for cholera. It includes individuals under 5, which differs from the definition given by WHO (individuals aged 5 years and above meeting these criteria). Since other microorganisms aside from V. cholerae can cause diarrhoea and vomiting leading to dehydration, some uncertainty could be introduced into our results because we included children under 5 years old in our study's definition of suspected cholera cases (Platt-Mills et al., 2015).

RECOMMENDATIONS

To effectively manage cholera in Abia State, Nigeria, it is imperative to allocate additional human and computing resources specifically dedicated to enhancing data collection and governance. Moreover, there is a critical need for refresher courses aimed at retraining health and epidemiology personnel in the timely and accurate collection of data, as well as proficient use of the SORMAS system. This step is pivotal in refining data collection techniques and ensuring robust data governance, which in turn will greatly contribute to the efficient management and control of future outbreaks.

Furthermore, urgent measures are required to bolster sanitation efforts, particularly in Aba and Umuahia, where prevalent pollution facilitates the spread of cholera. Initiatives should be implemented to compel residents to actively participate in these sanitation endeavours.

Additionally, it is imperative to disseminate awareness regarding cholera outbreaks, transmission modes, and control strategies through diverse communication channels such as radio, television, and social media. This multi-pronged approach is crucial in curtailing the spread and mitigating the impact of cholera in the state (Idogha et al., 2019).

CONCLUSION

In conclusion, our study sheds light on the critical epidemiological factors influencing cholera outbreaks in Abia State, Nigeria, from 2021 to 2023. The findings underscore the urgent need for strengthened public health interventions, including improved sanitation practices, particularly in densely populated urban areas. Additionally, our predictive model provides a valuable tool for anticipating and mitigating future outbreaks, offering a pathway towards more effective cholera control measures. However, it is imperative to acknowledge the limitations in data availability and the need for enhanced surveillance systems. By implementing these recommendations, we aim to pave the way for a healthier and more resilient Abia State, better equipped to tackle the challenges posed by cholera and other infectious diseases. This research serves as a crucial foundation for evidence-based policymaking and resource allocation in the fight against cholera in Abia State, Nigeria.

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