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The 2023 Dengue Fatality in Bangladesh: Spatial and Demographic Insights

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Highlights

- Dhaka City is identified as the primary hotspot for deaths caused by dengue.
- No significant hotspots for dengue deaths have been identified outside Dhaka.
- Neighboring districts have a substantial spatial influence.
- Demographic factors significantly impact dengue deaths in Bangladesh.
- Dengue deaths were due to dengue shock syndrome, DSS (74%), expanded dengue syndrome, EDS (17%), dengue hemorrahgic fever, DHF (7%) and associated with comorbidities (2%).

The 2023 Dengue Fatality in Bangladesh: Spatial and Demographic Insights

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Abstract

Introduction: In 2023, Bangladesh faced the largest dengue outbreak resulting in 321,179 confirmed cases and 1,705 fatalities. This study aims to characterise dengue fatalities and analyse their determinants and spatial influence.

Methods:

Using data from the Management Information System of the Ministry of Health and Family Welfare, we characterised dengue mortality and conducted a linear regression analysis to determine the impact of age groups and gender on case fatality rate (CFR). We employed a Geographically Weighted Poisson Regression model to assess the spatial influence and impact of population factors.

Results: Women had a higher CFR compared to males (0.75% vs 0.38%, $p<0.05$). Among the recorded deaths, 74% (n=1262) developed dengue shock syndrome, 17% (n=290) expanded dengue syndrome, and 7% (n=119) dengue hemorrhagic fever. 10-year age groups significantly impacted CFR (estimate: 0.03, $p < 0.01$), suggesting that each additional decade increased CFR by 30% while gender was insignificant. Higher deaths were observed in the southern regions while spatial clusters were primarily concentrated around Dhaka City, the epicentre of the outbreak. Substantial effects from neighboring districts were also identified.

Conclusion: Bangladesh’s 2023 dengue outbreak resulted in significant mortality, particularly among older age groups. Fatalities were clustered in Dhaka city and its neighbouring districts, especially in the south.

Keywords. dengue mortality, geographical influence, population burden, spatial cluster, Geographically Weighted Poisson Model

1. Introduction

The global dengue outbreak has intensified in recent years, posing a serious public health challenge, particularly in tropical and subtropical regions [1, 2]. Globally, 390 million dengue infections are predicted with South-East Asia and South America being mostly affected [3, 4]. The incidence has surged due to factors such as urbanisation, climate change, and increased international travel, which facilitate the spread of *Aedes* mosquitoes, the primary vectors of the dengue virus [1, 3]. The complex epidemiology of dengue virus, with four distinct serotypes, increases the risk of severe cases of secondary infections and complicates control efforts [2, 5].

Bangladesh is experiencing one of its worst dengue outbreaks in history, with a significant surge in cases and deaths overwhelming the healthcare system. The outbreak, concentrated in urban areas such as Dhaka, has been exacerbated by the monsoon season, which creates ideal breeding conditions for *Aedes* mosquitoes [6, 7]. Hospitals are struggling to cope with the large influx of patients, many of whom are suffering from severe dengue symptoms, including high fever, severe pain, and potentially life-threatening complications such as hemorrhagic fever and dengue shock syndrome. Public health authorities are intensifying efforts to control mosquito populations through community engagement, vector control measures, and public awareness campaigns. In 2023, over 20 hospitals throughout the country have opened separate dengue cells to manage dengue patients and reduce case fatality [6]. Despite these efforts, Bangladesh experienced 1,705 dengue deaths in 2023 which was significantly higher than the previous 23 years (849 deaths between 2000 and 2022) [6, 8].

The large number of dengue-related deaths in Bangladesh last year has led dengue to emerge as a severe public health crisis, where several factors are suspected to have contributed to the high mortality rate. Dhaka is suspected to be one of the largest dengue mortality hotspots.

Other metropolitan cities- Chittagong, Rajshahi, Khulna, Barisal, Sylhet, Rangpur and Mymensingh are also highly populated and may have higher concentration of dengue morality. The southern division of Bangladesh had a higher incidence of dengue compared to the northern divisions (2.30 vs 0.50 per thousand population) [8].

The geographical influence or spatial dependence may have a significant impact on dengue mortality due to the infectious nature of the disease in addition to population-related factors, for instance, population size, population density, urban-rural ratio, distance from the epicenter of the outbreak [9, 10]. Several attempts were made earlier to investigate the geographical influence or spatial dependence, and other factors including climate variables and ecological factors on dengue morbidity and transmission [2, 11-17]. However, no studies used actual geo-location of the death cases. We used extracted geo-coordinates of all deaths cases from the address listed in the hospitals. In this study, we aim to characterise the dengue-related deaths including age, and gender, and investigate the spatial relationship between dengue deaths and population factors including population size, density, and rural and urban population ratio.

2. Materials and Methods

2.1 Data source

We gathered publicly available dengue death records from 1 January to 31 December 2023 from the daily press release of the Management Information System (MIS) of the Ministry of Health and Family Welfare, Bangladesh [18]. The MIS dataset recorded the age, gender, date of hospitalisation and cause of death for dengue patients, as determined by the attending physicians at each hospital following the National Guidelines for Clinical Management of Dengue Syndrome [19]. We also collected the addresses of the death cases from the MIS which were anonymised by providing approximate locations used in this study. Therefore, our dengue death dataset which contains a record of 1,705 individuals provides a unique opportunity to study the concentration, patterns and geographical variations of dengue deaths in Bangladesh. The MIS dataset also recorded the cause of death for dengue patients, as determined by the attending physician at each hospital, following the National Guidelines for Clinical Management of Dengue Syndrome [19]. Causes of death were classified into three categories: 1) dengue shock syndrome, 2) expanded dengue syndrome, and 3) dengue hemorrhagic fever 4) Dengue fever with co-morbidity. We also gathered district-wise population and geographical data from the Statistical Yearbook Bangladesh 2023 published by the Bangladesh Bureau of Statistics including population size, the ratio of rural and urban population (which is a proxy variable for urbanisation), and distance of each district from the capital city, Dhaka. Additionally, we calculated population density by dividing the population size by the area of each district.

2.2 Variables

The response variable for this study is the death of a person due to dengue. We used the definition used by the Ministry of Health and Family Welfare, Bangladesh for dengue cases and deaths. For the exploratory study, we used the individual deaths by location and investigated their clustering patterns. As one of our main objectives was to investigate the impact of geographical variations and population factors on the dengue deaths, we took districts as the spatial unit for our analysis. There are 64 districts in Bangladesh, and we gathered district-level data on population size, density, urban-rural ratio, and distance from the epicenter of the outbreak, which is the capital city Dhaka. Therefore, the number of deaths in each district is considered as the response variable for the spatial regression analysis and population size, density, urban-rural ratio, and distance from the epicenter of the outbreak as the explanatory variables for the analysis. These variables were selected based on their established associations with dengue transmission dynamics. Both population size and population density are expected to influence dengue mortality, as larger and denser populations present greater opportunities for mosquito-human contact and a higher absolute number of individuals at risk of illness. Urbanisation could also play a critical role, as urban areas typically provide favourable conditions for mosquito breeding, including the presence of standing water in construction sites, blocked drainage systems, and water storage containers. Therefore, districts with higher urban-rural ratios may be associated with elevated transmission rates. Additionally, the geographic location of the epicentre (Dhaka) may further influence spatial patterns of mortality. Districts in closer proximity to Dhaka may experience more rapid disease spread due to increased human mobility (e.g., commuting, trade) and disparities in healthcare resource allocation.

2.3 Statistical analysis

To understand the nature of age, sex, daily distribution and causes of dengue deaths, we performed an exploratory analysis. A linear regression model was applied to reveal the linear trend of dengue case-fatality rate with age and sex. We applied spatial analysis techniques including the kernel density estimation and the spatial inhomogeneous Poisson process. The kernel density estimation is a nonparametric technique for density estimation with a known density function (referred to as the kernel) averaged across the observed data points to create a smooth approximation [20]. The spatial inhomogeneous Poisson process is the simplest non-stationary spatial point process where events occur with a spatially varying intensity function $\lambda(u, s)$, $(u, s) \in W$, unlike the constant intensity of a homogeneous Poisson process [20].

A Geographically Weighted Poisson Regression (GWPR) model was fitted to identify the impact of the potential factors while taking into account the impact of the neighboring units[21]. The model can be written in the following form,

$$ln(y_i) = \beta_0(u_i, v_i) + \sum_{k=1}^{p} \beta_k(u_i, v_i)x_{ik} + \epsilon_i$$

where y_i is the number of dengue deaths in the *i*th district in a year, β_0 is the intercept, β_k is the coefficient of the *k*th explanatory variable, x_{ik} is the value of *k*th variable for the *i*th district, (u_i, v_i) is the location (longitude, latitude) of the *i*th district and ϵ_i is the error term. We used an adaptive bandwidth and the exponential kernel function to calculate the weights of the neighboring districts during model calibration. All analyses were performed in R platform with packages 'base', 'spatstat' and 'GWmodel'. We used 'gpplot2' package for the plots.

3 Results

3.1 Descriptive measures

In 2023, Bangladesh experienced its deadliest dengue outbreak. Among the 321,179 confirmed dengue cases, 1,705 died with a case-fatality rate (CFR) of 0.53%. Among the 128,569 female cases, 970 died (CFR: 0.75%) while 735 of the 192,610 male cases died (CFR: 0.38%), demonstrating a significant difference in the CFR by sex ($p<0.05$). The median age of all fatal cases was 40 years (Interquartile range, IQR = 30) while the median age was 45 years (IQR = 35) for males and 40 years (IQR = 28) for females. Women and older adults were disproportionately affected, with females showing a higher case fatality rate (CFR) compared to males (57% vs 43%). Additionally, the CFR was notably higher among individuals aged between 20 and 75 years (Fig 1). Among the recorded deaths, 74% (n=1262) developed dengue shock syndrome (DSS), 17% (n=290) expanded dengue syndrome (EDS), and 7% (n=119) dengue hemorrhagic fever (DHF) (Fig 1).

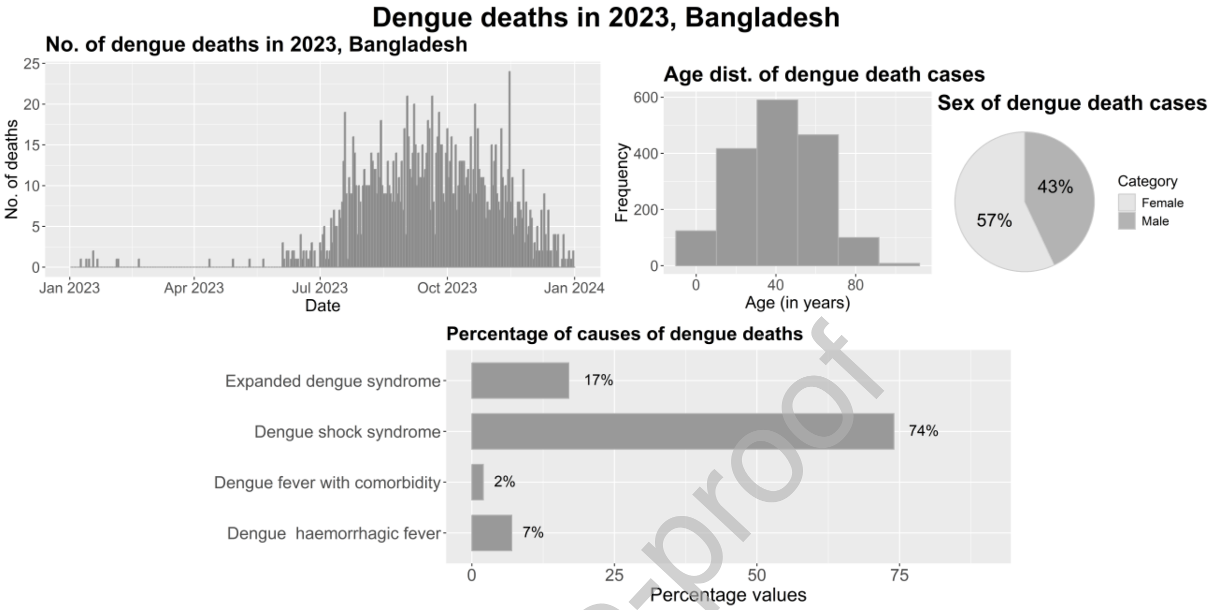

Fig 1: Distribution of daily deaths, age, and sex and causes of dengue related deaths in Bangladesh in 2023.

3.2 Case fatality analysis

The linear regression analysis of CFR revealed an approximately linear increase with age for both males and females. Our findings indicate that age, measured in 10-year increments, significantly impacts CFR (estimate: 0.03, $p < 0.01$), suggesting that each additional decade increases the fatality rate by 30% (Fig. 2). Although females exhibited a higher CFR, this association was not statistically significant (estimate: 0.09, $p = 0.71$). Thus, our study highlights age as a key determinant of CFR, while gender does not appear to have a statistically significant effect, despite females accounting for 57% of recorded fatalities.

Fig 2: Case fatality rate increases with age: Linear regression analysis

3.3 Clustering analysis

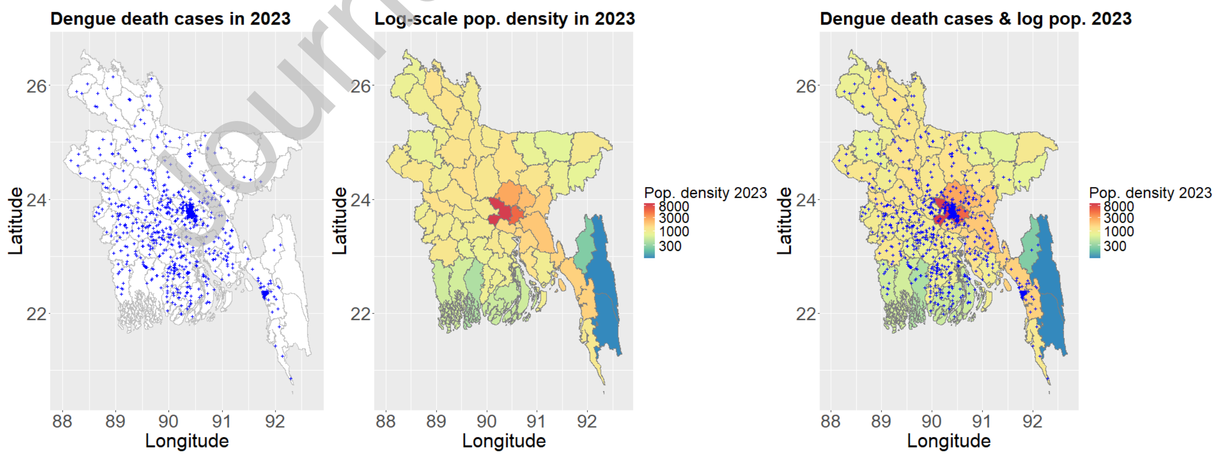

Fig. 3: Spatial plot of dengue deaths with population density in Bangladesh for 2023

We first plotted the dengue-related death cases in Fig. 3(Left), showing a widespread distribution of cases all over Bangladesh. However, Dhaka City showed a great concentration of death cases and a slightly higher concentration in a few districts in the Southern part of Bangladesh. The Dhaka division, particularly Dhaka city, was the most affected area, accounting for the majority of the dengue deaths as seen in Fig. 3(Left). We also plotted the population density by districts as shown in Fig. 3(Middle) to compare the mortality levels in each district. The combined plot (Fig. 3) indicated a correlation between the population density and dengue mortality.

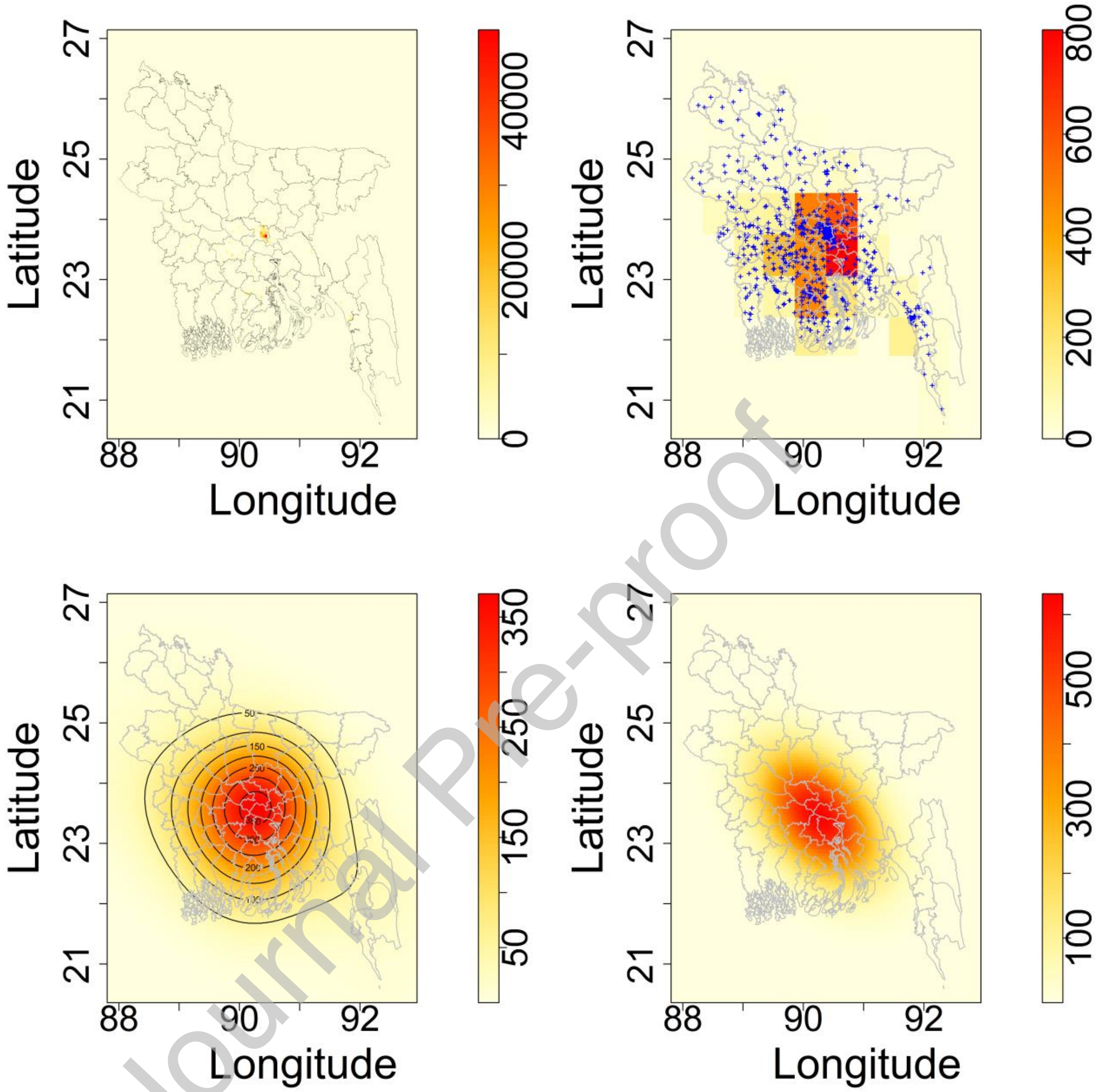

Fig. 4: Clustering pattern of deaths due to dengue virus infection in Bangladesh in 2023

The clustering analysis showed that Dhaka city was the hotspot of dengue mortality (Fig. 3(Left)). However, a few other concentrations of mortality were found in the Southern districts of Bangladesh as highlighted in Fig. 3(Middle) including Narayanganj, Munshiganj, Faridpur, Shariatpur and Chandpur districts. We also generated the contour plot of dengue mortality (Fig. 4) which identified Dhaka and its surrounding and several southern districts as hotspots of dengue mortality. A similar result was observed when we fitted a spatial inhomogeneous Poisson process. Higher intensities of dengue mortality were found in Dhaka City and nearby districts including the districts from the Southern part of Bangladesh.

3.4 Geographically Weighted Poisson Regression (GWPR) model

We fitted and evaluated a GWPR model with adaptive bandwidth and exponential kernel function. The bandwidth measures the distance-decay in the weighting function and indicates the extent to which the resulting local calibration results are smoothed. Spatial kernels with a small bandwidth have a steeper distance-decay weighting function and produce rougher surfaces than spatial kernels with a large bandwidth [21]. We applied an adaptive bandwidth that automatically selects the optimal bandwidth and the exponential kernel function for the weights of the neighboring districts during the model calibration. The corrected Akaike information criteria (AICc) was 1243.046 and the Pseudo R-square value was found to be 0.8480027, both of which showed a reasonably good fit of the model (Table 1). The observed and predicted number of deaths in 2023 by districts showed a reasonably accurate fit. Therefore, the model can be used to predict the number of dengue deaths in each district given the values of the covariates: population size of districts, population density, urban-rural population ratio and distance from Dhaka.

Table 1: Results of the fitted Geographically Weighted Poisson Regression (GWPR) model

4 Discussion

In 2023, Bangladesh faced significant challenges with dengue fever outbreaks, revealing distinct patterns across age and gender. We have characterised the fatalities caused by dengue virus in 2023. Our data showed that an increase of age group by 10 years increased the CFR by 30% while gender did not show any statistical significance. Dengue related deaths were mostly due to dengue shock syndrome (74%), expanded dengue syndrome (17%), and dengue hemorrhagic fever (7%). These insights underscore the importance of tailored public health strategies to address dengue outbreaks effectively across diverse age and gender demographics in Bangladesh.

Increased age has been a significant determinant of dengue-related fatalities in Bangladesh. Lifetime cumulative exposure to DENV raises the likelihood of elderly individuals being exposed to multiple serotypes, which ultimately increases the risk of developing severe dengue [9, 22]. All four serotypes of dengue have been detected in Bangladesh over time, leading to significant outbreaks shortly after the virus was introduced [1, 12]. Our earlier analysis showed higher fatality rates among both the elderly and women [6]. However, in this study, our analysis revealed that each additional 10-year age group increases the CFR by 30%, while gender no longer showed a significant effect. These findings are particularly crucial in a context where multiple serotypes are circulating, heightening the risk of exposure to several serotypes and developing a risk of severe dengue. These findings could have significant implications for other dengue-endemic countries in identifying high-risk individuals for managing severe dengue.

The outbreak was widespread, affecting all 64 districts of the country. The most impacted areas were primarily in the Dhaka division, particularly Dhaka city, which accounted for 52.8% of the cases and 78.9% of the deaths. Other significantly affected divisions included Chittagong (13.2% of cases, 9.2% of deaths), Dhaka division excluding Dhaka city (11.6% of cases, 2.8% of deaths), and Barisal (10.5% of cases, 4.3% of deaths). The Sylhet division reported the lowest number of cases and no deaths [8]. The spatial pattern of dengue deaths in Bangladesh during the 2023 outbreak identified in this analysis highlights significant regional disparities, with the most severe impact concentrated in specific areas.

The majority (74%) of the deaths in this outbreak resulted from dengue shock syndrome (DSS) followed by expanded dengue syndrome (EDS) (17%) with 7% due to dengue hemorrhagic fever (DHF). Despite advancements in medical knowledge, the exact pathophysiology of DSS, DHF and EDS remains unclear. This underscores the need to enhance understanding on how the virus interacts with its host and the factors that promote serious consequences. Given the variety of clinical and often atypical manifestations of DSS, EDS and DHF and the lack of specific biomarkers, healthcare seeking is frequently delayed and timely diagnosis and management is often challenging and largely dependent on clinical judgement. While evidence-based guidelines are being developed for these critical care scenarios, such research are seldom conducted in the LMIC settings where the illness burden is high and resources typically scarce [23, 24]. Raising awareness of clinicals to the atypical features of severe dengue infections during epidemics and their evidence-based management can help to establish early diagnosis and prompt treatment for dengue with unusual manifestations and reduce mortality.

Several factors likely contributed to the higher number of recorded deaths in the capital city and some other districts including Narayanganj, Munshiganj, Faridpur, Shariatpur and Chandpur. Firstly, Dhaka continues to have the best treatment facilities in the country, particularly for intensive care units (ICUs), and a higher number of tertiary care hospitals. As a result, patients with severe dengue and/or comorbidities from across the country were likely referred to Dhaka for better management [6, 8, 25]. Second, historically, Dhaka has been the epicenter of dengue disease and thus people living in the capital city were probably already exposed to one of the serotypes circulated in the country before. Serological studies showed that more than 80% of the people in Dhaka had antibodies against Dengue [26]. The Dengue virus serotype 2 (DENV-2) and the serotype 3 (DENV-3) were the predominant strains during the 2023 outbreak. These serotypes are known to cause more severe clinical outcomes, especially when individuals are reinfected with a different serotype than the one, they were previously exposed to—a phenomenon called antibody-dependent enhancement (ADE). In prior years, Dengue virus serotype 1 (DENV-1) had been more common in Bangladesh, meaning many people were now being exposed to DENV-2 or DENV-3 for the first time after an earlier infection, leading to more severe symptoms such as dengue haemorrhagic fever and dengue shock syndrome [8, 25]. The shift in serotype prevalence combined with a population lacking immunity to these more virulent strains contributed significantly to the higher case fatality rate [8, 25, 27]. Finally, some patients admitted to hospitals in Dhaka were shifted from nearby districts increasing the death count of the city. However, several other districts also had high concentration of dengue deaths. As a result, we propose to investigate the cause of dengue-related deaths more elaborately [28].

The impact of investigated factors including population size, population density, urban-rural ratio, and distance from Dhaka on 2023 dengue mortality in Bangladesh is multifaceted and interconnected. Firstly, larger population sizes generally correlate with increased dengue cases due to higher human-vector interaction and a greater likelihood of virus transmission [22, 28]. In some parts of Dhaka city, there are shortages of water supplies during different periods of the day. Accumulated water in artificial containers, stagnant water at construction sites, clogged gutters, uncovered rain barrels, etc. are prime breeding grounds for *Aedes* mosquitoes [25, 29]. On the other hand, rural areas with lower population densities may still be at risk, albeit to a lesser extent, depending on environmental factors and access to healthcare [30].

The urban-rural ratio influences dengue mortality by determining the distribution of healthcare resources and infrastructure [30]. While population size and density amplify the spread of dengue, the urban-rural divide and proximity to Dhaka significantly influence mortality rates through differential access to healthcare and varying levels of preparedness to manage dengue outbreaks effectively. Addressing these factors collectively through targeted public health strategies and infrastructure development is crucial for mitigating dengue mortality in Bangladesh.

Effective management of dengue fever, including reducing mortality rates, requires a multifaceted approach addressing several key factors including herd immunity, previous infection, co-circulation of serotypes, vector and environmental surveillance, and high-resolution data. In the context of dengue, achieving herd immunity through vaccination is complex due to the presence of four serotypes [31]. Immunity to one serotype does not confer protection against the others. Vaccination programs targeting all four serotypes (tetravalent vaccines) are crucial to developing herd immunity without increasing the risk of severe disease. However, the effectiveness and long-term impact of such vaccines are still under evaluation, requiring continuous monitoring and adaptation [32]. Previous infection with one dengue serotype influences the immune response to subsequent infections. While initial infection often results in mild to moderate illness and confers lifelong immunity to that specific serotype, secondary infections can be more severe. Understanding the dynamics of previous infections and the immune response is critical for predicting disease patterns and tailoring public health interventions [29]. The simultaneous circulation of multiple dengue serotypes complicates control efforts and increases the risk of severe disease. Monitoring the prevalence and distribution of different serotypes is essential for identifying at-risk populations and tailoring vaccination strategies [33]. Current gaps in vector surveillance, particularly in resource-limited settings, hinder timely and effective intervention measures. Enhanced surveillance techniques, including geographic information systems (GIS), remote sensing, and community-based monitoring, can improve the detection of mosquito breeding sites and guide targeted vector control efforts [34]. Additionally, integrating climate and weather data can help predict outbreaks and implement preemptive measures [25]. Accurate and high-resolution data on dengue cases, vector populations, and environmental conditions are vital for effective disease management [35]. Current surveillance systems often suffer from delays, underreporting, and insufficient granularity. Ideally, a more granular analysis could be conducted by incorporating data on the distance between each patient's point of infection and the hospital where care was received, along with detailed information on patient movement within healthcare facilities and the sequence of clinical episodes experienced prior to death. Therefore, improved data collection methods, real-time reporting, and integration of various data sources can enhance situational awareness and response strategies. Machine learning and artificial intelligence can analyse complex datasets to identify patterns and predict outbreaks, enabling proactive interventions.

5 Conclusions

Age, measured in 10-year increments, significantly impacts the dengue-related fatalities suggesting that each additional decade increases the fatality rate by 30%. The majority of deaths were due to DSS and EDS. These findings are particularly crucial in a context where multiple serotypes are circulating and could have significant implications for other dengue-endemic countries in identifying high-risk individuals for managing severe dengue. In Bangladesh, dengue mortality is heavily concentrated in certain regions, particularly in and around Dhaka, the capital city of Bangladesh. This is indicative of a spatial clustering effect where areas closer to Dhaka experienced higher mortality rates. The capital city's healthcare infrastructure, although better than rural areas, might be overwhelmed during peak outbreaks, contributing to higher mortality rates. There is a significant spatial relationship in dengue mortality rates, meaning that districts closer to each other tend to have similar mortality rates. This suggests that dengue transmission and resultant mortality are influenced by regional factors and local interactions. Vaccination, improvement of diagnostics, clinical management dengue patients with continued monitoring and spatial analysis of dengue cases can help in making informed decisions and timely interventions to reduce dengue mortality. Policies should be dynamic, adapting to the changing patterns of dengue transmission and mortality, especially considering urbanization trends and climate change impacts.

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Conflict of Interest

The authors declare no conflict of interest.

Disclaimer

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The views expressed in this publication are those of the author(s) and not necessarily those of the Department of Health and Social Care.

Data Availability Statement

The data that support the findings of this study are available from the Management Information System (MIS), The Directorate General of Health Services, Ministry of Health and Family Welfare, Bangladesh. Restrictions apply to the availability of these data. Partial data are available at Daily Dengue Press Release (https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report).

Ethical approval

Not required.

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Table 1: Results of the fitted Geographically Weighted Poisson Regression (GWPR) model

Summary of GWPR coefficient estimates					
Variables	Minimum	1st Quartile	Median	3rd Quartile	Maximum
Intercept	-1.2457e+01	-1.0568e+01	-9.5032e+00	-8.1076e+00	-6.6098
log(PopSize)	5.3588e-01	6.6801e-01	7.8156e-01	8.9401e-01	1.0156
PD	-1.6140e-04	-1.0556e-04	-5.4483e-05	2.1390e-05	0.0002
URR	8.5173e-03	1.1079e-02	1.1961e-02	1.2542e-02	0.0135
Distance	-2.1181e-03	-4.5390e-04	1.5349e-04	2.2275e-03	0.0055
Pseudo R-square value: 0.8480027					

Declaration of interests

☒The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests: