**Title: The 2023 Fatal Dengue Outbreak in Bangladesh Highlights a Paradigm Shift of Geographical Distribution of Cases**

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**Abstract (word count: 330, target 300).**

**Background:** In 2003, Bangladesh experienced its largest and deadliest outbreak of Dengue virus (DENV)), reporting the highest-ever recorded annual cases and deaths caused by Dengue. WeIn the current study, we aimed toto characterize the geographical transmission dynamics of the DENVDENV in Bangladesh.

**Methods:** For the period 1 Jan – 31 Dec 20232023, we extracted and analyzed data on Dengue from the Management Information System (MIS) of the Ministry of Health and Family Welfare, Bangladesh. Population, Meteorological, and Geographical data were extracted from the Bangladesh Meteorological Department of and Bureau of Statistics. annual The per district number of Dengue cases/100,000 population was calculated and linkages with geographical distribution using a generalized impact of several factors including urban-rural ratio, population density, distance from Capital Dhaka, average daily temperature, and rainfall to the at the division level Generalized linear mixed model

**Results:** The number of Dengue cases reported in 2023 was 1.3 times higher than the total number of recorded in the past 23 years from 2000 to 2022 (321,179 vs 244,246),), with twice as many deaths than the total fatalities recorded in the past 23 years (1705 vs. 849). The 2023 outbreak was characterized by an earlier surge of dengue cases with exponential growth in Dhaka city up until the end of July and then an increase in cases outside Dhaka. The southern districts of Bangladesh had a higher incidence with Manikgonj (0.83), Pirojpur (0.61), Barisal (0.53), Magura (0.49), and Barguna (0.45) being the top five. Southern divisions had monthly higher relative change (increase) of dengue cases from previous months. Population density of the district (r=0.44, P<0.05) was positively correlated with district-wise dengue cases, whereas distance from the capital city Dhaka was negatively correlated (r=-0.30, p<0.05).The urban and rural population ratio of the district (IRR: 1.04 95% CI: 1.03-1.04), temperature (IRR: 1.13, 95% CI: 1.11-1.14), and rainfall (IRR: 0.99, 95% CI: 0.98-0.99) were associated with dengue cases.

**Interpretation/Conclusions**: A major geographical shift of the Dengue cases from the capital city Dhaka to different districts of Bangladesh with a higher incidence of cases in the southern district of Bangladesh. Continuous monitoring and identifying specific drivers of Dengue in Bangladesh is required for effective control measures to be implemented and reduce the high morbidity and mortality rates.

**Introduction**

Bangladesh experienced its largest and deadliest dengue outbreak, reporting the highest-ever recorded annual cases and deaths by dengue virus (DENV) infection in 2023. Between 2000 and 2022, Bangladesh reported a total of 244,246 dengue cases including 849 deaths with a case-fatality rate of 0.49% 1. In 2023 alone, the number of cases and deaths surpasses the previous 23 years' cumulative numbers: 320,835 cases and 1,699 deaths respectively until 27 December 2. While this number is shocking and concerning, epidemiologically these figures are not unexpected based on the trend of dengue cases in the last five years (2018-2022): more than 82% of cases (n=202,425) and 69% of deaths (n=550) of last 23 years were reported during this period 1.

Historically, most of the dengue cases in the country have been reported in urban areas, with a particular concentration in the capital city of Dhaka 3 except a few years like 2019 when almost half of the cases were reported from outside Dhaka 4. Sporadic cases of dengue were documented in Dhaka in the 1960s, preceding the significant outbreak that occurred in 2000 in major cities, including Dhaka, Chittagong, and Khulna 3,5. Serological studies conducted across the country demonstrated substantial spatial heterogeneity in seropositivity with seroprevalence ranging from as high as 88% in urban Chittagong to as low as 3% in rural Maulvibazar in Sylhet division 6. In the capital city Dhaka, the seropositivity of DENV ranged from 36 to 85% 6. However, the 2023 outbreak in Bangladesh revealed a paradigm shift in the occurrences of cases in variable geographic regions. Of 320,835 cases, 207,716 (65%) were reported from outside Dhaka, whereas more than 58% (979 of 1699) deaths were recorded in Dhaka.

*Aedes aegypti,* the primary vector of dengue virus is known for its preference for urban and suburban environments7. Several factors contribute to this affinity for urban areas including the presence of artificial containers, human habitation and blood hosts, microclimate in urban areas, and adaptability 7. On the other hand, *Aedes albopictus*, the second important vector of the dengue virus exhibits a broader habitat range including rural and urban areas8. Other factors that affect the spread of the dengue virus are urbanization, population density, rainfall and watering distribution systems, and temperature 9. As Bangladesh has recently experienced a country-wide distribution of dengue cases, it is important to understand the factors that affect the geographical distribution of dengue cases in Bangladesh. The objective of this study was to characterize the geographical transmission dynamics of dengue virus infection in Bangladesh and the spreading of dengue virus infection between Dhaka and outside the capital city, and also to quantify the impact of urban-rural ratio, population density, distance from Dhaka, average daily temperature and rainfall at the division level.

**Methods:**

**Source of the data:** We collected the data on all dengue cases and death records from January to December 2023 from the daily press release of the Management Information System (MIS) of the Ministry of Health and Family Welfare, Bangladesh. The MIS defined dengue cases based on clinical symptoms (including fever and rash) and/or laboratory tests for IgM or IgG antibodies to DENV and nonstructural 1 protein (NS-1) of DENV 10. MIS collected dengue case data from 77 hospitals based in Dhaka city (20 public and 57 private hospitals) and the central district hospital of 63 other districts of the country including the hospitalized patients in tertiary care medical college hospitals (Ref: JME paper 2023). We collected 3-hourly meteorological data (temperature, humidity and daily rainfall) from the Bangladesh Meteorological Department (BMD) over the period 2000–2023 from the meteorological station located in Mirpur, Dhaka (Lat 23.46, Lon 90.23), Chittagong (Lat 22.16, Lon 91.49), Rajshahi (Lat 24.22, Lon 88.42), Rangpur (Lat 25.44, Lon 89.14), Sylhet (Lat 24.54, Lon 91.53), Barisal (Lat 22.45, Lon 90.20), Khulna (Lat 22.47, Lon 89.32), and Mymensingh (Lat 24.43, Lon 90.26).

**Relative increase of dengue cases by division**

We have estimated monthly relative changes in dengue cases in each division. The relative changes (an increase or decrease) of a division (e.g..., Chattogram) of dengue cases for a month (e.g., February) were estimated with the formula as shown below -(Total number of cases reported in Chattogram division in specific month of 2023) / Total number of cases reported in Bangladesh in that month of 2023) \*100

*RCt*is the relative changes of dengue cases in *t* month, is the number of dengue cases reported in X city, *Nt*is the total number of cases in Bangladesh in t month. To avoid any complication of 0 cases in any city in any month we added 1 dengue case in both numerator and denominator.

**Incidence by district**

We calculated the annual cumulative district-wise incidence of dengue cases by taking the cumulative annual number of dengue cases of each district divided by the population of the district shown as -(The total number of dengue cases in a district in 2023) / Total number of populations of that district) \*1000. We then generated a map for Bangladesh showing using district-wise incidence of dengue cases in 2023.

**Statistical Analysis**

We compared the dengue cases and deaths of the year 2023 and previous years (2000-2022), prepared graphs, plots, and maps, and compared these data with meteorological data. We reshaped our dataset by incorporating division-wise dengue case data as outcome variables. We further collected division -wise population and geographical data from the Statistical Yearbook Bangladesh 2022 published by the Bangladesh Bureau of Statistics 11 including population size, the ratio of rural and urban population, and distance from the capital city, Dhaka. Additionally, we calculated population density by dividing the population size by the area of each division. We draw an imaginary east-west line in the middle of Dhaka city to compare the incidence and weather pattern of the southern (Chattogram, Khulna and Barisal) and northern divisions (Rajshahi, Rangpur, Mymensingh, and Sylhet). Dhaka division was excluded from the separation.

We employed a generalized linear mixed model (GLMM) with negative binomial distribution to model the division-wise daily dengue counts enhancing modelling flexibility through the inclusion of random effects 12. We introduced the random effect into the GLMM model to account for the time series effects in the data.. The choice of negative binomial distribution allowed us to model response data appropriately with extra-variations into the data (overdispersion) 13. Parameter estimation in GLMMs is challenging due to the integration of random effects in the likelihood function 14. However, our model results are presented as adjusted incidence rate ratios (IRRs), considering dengue deaths, the urban-rural ratio (as an urbanization proxy), population density, and distance from Dhaka, along with corresponding 95% confidence intervals. The components of the NB-GLMM are given below:

* Distribution: ~ Negative Binomial (,

~ *N*(,

* Linear predictor:
* Link function: .

where denotes the number of cases in day *i* on division *j* (*i* = 1, 2, ⋯, 365; *j* = 1, 2, ⋯, 8), is the linear predictor, is the intercept, is the fixed effect due to day *i* for the *j*th covariate, and is the random effect due to division *j* 15.

The specific form of our model can be given by

where is the population density, is the urban-rural ratio, and is the distance from Dahka for the division *j*, is the daily average temperature and daily total rainfall for day *i* and division *j*.

**Results:**

During 2023 (1 Jan to 31 December), a total of 321,179 dengue cases have been reported with 1,705 deaths (case fatality rate: 0.53%). The number of cases reported in 2023 is 1.3 times higher than the number of reported cases in the past 23 years (321,179 vs 244,246) and two times more deaths than the number of fatalities recorded in the past 23 years (1,705 vs. 849) in the country **(Fig 1)**. The number of reported cases and deaths was higher in each month in 2023 compared to the average number of cases or deaths in the corresponding months from 2000 to 2022 **(Fig 1)**. Among the dengue cases, 40% were female and 56% were below 30 years of age group. A total of 110,008 cases were reported from the capital City Dhaka including 980 deaths (case-fatality rate: 0.89%) and 211,171 cases were reported from outside Dhaka including 725 deaths (case-fatality rate of 0.34%).



**Fig 1:** The number of dengue cases and deaths reported in 2023 vs 2000-2022 in Bangladesh. Log 10 base is used for the display of the cases and deaths for the convenience of visualization and comparison.

Bangladesh experienced a higher amount of rainfall in 2023 compared to the average annual rainfall of the period 2000-2022. The average rainfall for the period 2000 to 2022 was 1915.75 mm whereas in 2023 total annual rainfall increased to 2160.70 mm **(Fig 2)**. In 2023, rainfall started earlier in the year with 75.8 mm of precipitation in March compared to an average of 45 mm amount of rainfall for the month of the period 2000-2022. There was a comparable range of temperature between 2023 and the period 2000-2022. In comparison to the mean temperature of 26.46 °C for the period 2000 to 2022, the temperature increased marginally to 27.06 °C in 2023 **(Fig 2)**.



**Fig 2:** The temperatures (°C) and rainfall (mm) of Bangladesh as recorded in a weather station in Mirpur, Dhaka, by Bangladesh Meteorological Department, Bangladesh for the period 2000-2022 vs. 2023.

**Relative changes in dengue cases in each division:**

Dhaka city was the primary outbreak site in 2023 and contributed to more than 50% of the total cases up until July and then cases started to increase outside Dhaka, where Dhaka division (excluding Dhaka city) and Chittagong division have been among the prominent sites of the outbreak **(Fig 3)**. In May, Dhaka city contributed more than 83% of the total cases in the country which dropped to 23.4% in December. The relative changes in dengue cases in different divisions became more evident after July when most divisions started to report an increased percentage of cases and Dhaka city started to report a lower percentage of cases **(Fig 3).** Bangladesh observed one of the largest festivals of the Muslim-majority country Eid-Ul-Adha on 28th July 2023 and many people traveled from Dhaka to their rural house located outside Dhaka. In November, the Dhaka division (except Dhaka city) reported almost 23% of dengue cases which was the highest percentage of dengue cases for any division in the country, the first record of surpassing the number of cases reported in Dhaka city by any division of the country (**Fig 3)**. The Sylhet division contributed less than 1% of cases throughout the year. The amount of annual total rainfall recorded in the northern divisions was 2638.13 mm as compared to 2026.50 mm rainfall in the southern division (p<0.01). The mean annual temperature recorded in the southern district was 26.60 °C as compared to 25.77 °C temperature of the northern divisions. The temperature of Dhaka division was 27.07 °C and rainfall was 2160.7 mm.



A screenshot of a graph

Description automatically generated

**Fig 3:** A (Top) The daily number of dengue cases in different divisions of Bangladesh (1 Jan – 31 Dec 2023). B (Bottom).The monthly relative changes of Dengue cases in each division in Bangladesh, 2023 from previous months. Although Dhaka city remains the centre of the outbreak, the percentage of cases has increased outside Dhaka city after July 2023.

We compared the number of dengue cases in the capital city Dhaka vs. the rest of the country in **Fig 4**. There was a parallel trajectory in both Dhaka city and outside until mid-April. After that, dengue cases started to increase exponentially in the capital city Dhaka which continued up until the end of July 2023, and then the number of cases outside Dhaka surpassed the capital city. Notably, dengue-related deaths were initially higher outside Dhaka City until February, after which an escalation within Dhaka City commenced and persisted till the end of the year.



**Fig 4:** The line graph of dengue virus infection in the capital city Dhaka and outside from 1 January to 31 December 2023. A large number of people from the capital city left Dhaka when Eid-Al-Adha was celebrated on the 28th of June and subsequently, dengue cases started to increase outside Dhaka.

District-wise, Dhaka district reported the highest amount of dengue with 113,233 cases, followed by Chittagong (14,200), Barisal (13,603), Manikganj (12,952), and Patuakhali (7,579). On the contrary, the lowest Dengue cases were recorded in Sunamganj (102), Maulvibazar (129), Panchagarh (187), Joypurhat (264), and Lalmonirhat (305). In terms of dengue-related deaths, Dhaka reported the highest death toll at 981, trailed by Barisal (167), Faridpur (138), Chittagong (106), and Khulna (41) district **(Fig 5)**.

For district-wise cumulative incidence, the districts located in southern part of Bangladesh had a higher incidence of dengue cases in 2023. Manikganj, a neighbouring district of Dhaka had the highest incidence of dengue with 0.83 cases per 1000 people, followed by Dhaka (0.77), Pirojpur (0.61), Barisal (0.53), and Magura (0.49). Conversely, the lowest Dengue cases were recorded in Sunamganj (0), Maulvibazar (0.01), Panchagarh (0.02), Sylhet (0.02), and Thakurgaon (0.02) district **(Fig 5)**.



**Fig 5: A (Left).** The distribution of dengue cases in different districts of Bangladesh, 1st Jan 2023 – 31st Dec 2023. **B (Right)** The incidence of dengue cases in each district in Bangladesh (1st Jan- 31st Dec 2023). A higher incidence of dengue cases is observed in the southern districts of Bangladesh. The horizontal line in the middle of the country divides the southern and northern divisions. The southern divisions (Khulna, Barisal, and Chattogram) have a higher mean annual temperature (26.60 vs 25.77 °C) but a lower amount of rainfall (2026.50 vs. 2638.13 mm) compared to the northern divisions (Rajshahi, Rangpur, Mymensingh, and Sylhet) in 2023.

**Correlation:** When compared with monthly dengue cases, a positive correlation was observed between population size and the number of dengue cases (r=0.44, p=<0.001) and deaths (r=0.43, p=<0.001). A similar association is evident in the relationship between population density and dengue cases (r=0.47, p=<0.001) and deaths (r=0.43, p=<0.001). Conversely, a negative correlation was identified between the distance of each district from Dhaka city and the occurrence of Dengue cases (r=-0.32, p=0.011) **(Fig 6)**.



**Fig 6:** The correlation coefficient of dengue cases and deaths in different districts and their population size, population density, and distance from Dhaka city. A positive correlation exists with the population density of the district and a negative correlation exists with the distance from the capital city Dhaka.

In the GLMM, a statistically significant positive association was identified between the dengue cases and urban and rural population ratio (IRR:1.04, 95% CI: 1.03-1.04), daily average temperature (IRR: 1.13, 95% CI: 1.11-1.14), and daily total rainfall of the division (IRR: 0.99, 95% CI: 0.98-0.99). Population density and distance from Dhaka exhibited weak negative associations without statistical significance (Table 2).

**Table 2: Factors associated with dengue cases in different divisions using a generalized linear mixed model during 1 Jan 2023 and 31 Dec 2023.**

|  |  |  |
| --- | --- | --- |
| **Variables** | **Incidence risk ratio (IRR)** |  |
| **95% Confidence Interval** | **P-value** |
| Urban-rural ratio | 1.04 (1.03 – 1.04) | <0.001 |
| Population density | 0.99 (0.99 – 1.00) | 0.056 |
| Distance from Dhaka (capital city) | 0.99 (0.99 – 1.00) | 0.005 |
| Daily average temperature | 1.13 (1.11 – 1.14) | <0.001 |
| Daily total rainfall | 0.99 (0.98 – 0.99) | <0.001 |
| Daily average relative humidity | 1.09 (1.08 – 1.09) | <0.001 |
| **Groups Name** | **Variance** | **Standard Deviation** |
| Location (Intercept) | 0.01652 | 0.1285 |
|  |  |  |
| **Akaike information criterion (AIC)** | **Bayesian Information Criterion (BIC)** | **Root Mean Square Error (RMSE)** |
| 23720.9 | 23774.8 | 181.804 |
| **Conditional *R2*** | **Marginal *R2*** | **Intraclass correlation (ICC)** |
| 0.436 | 0.435 | 0.002 |







In the latest epidemiological report on Dengue fever, it has been observed that the highest number of reported cases, totaling 27,439, falls within the age category of 21-30 years. However, when considering mortality, the highest number of deaths, reaching 321, is found in the 31-40 age group. Surprisingly, both the incidence of Dengue cases and associated deaths are notably lower among individuals aged over 70 years. Further analysis by gender reveals a significant difference in the distribution of Dengue cases and deaths. While the number of reported cases is lowest among females, the mortality rate is highest within the same sex group. Examining the duration of hospital stays among Dengue patients, a concerning pattern emerges. The majority of deaths occur within the first day of hospitalization, indicating that fatalities are occurring immediately after admission, within 24 hours. These findings underscore the importance of targeted intervention strategies, particularly for high-risk age groups and immediate medical attention upon hospital admission to mitigate Dengue-related mortality.

**Discussion:**

In addition to very high number of dengue cases and deaths, Bangladesh’s 2023 dengue outbreak shows some unique characteristics including i) a geographical shift of cases from inside the capital city to outside Dhaka, ii) a very high case-fatality rate of dengue cases within capital City Dhaka, iii) early onset and surge of cases in Dhaka followed by spreading of cases across the country iv) a higher incidence of dengue cases in the southern districts of Bangladesh.

Several drivers contributed to the largest outbreak of dengue fever in Bangladesh. First, the dengue serotype -2 (DENV-2) reappeared in Bangladesh after 2018 16. The absence of the serotype allowed a large proportion of the population to be immunologically naïve as the city experienced more than 4% annual growth of population. Second, the outbreak in 2022 continued to 2023 with a relatively warmer year and persisting rain later in the year allowing more than 5024 cases in December 2022 compared to the monthly mean of 188 cases for December in Bangladesh (2000-2021) 16. Thus, the year 2023 started with as many as 566 cases in January compared to the monthly mean of 126 cases in Bangladesh (2000-2021) 16. Third, unusually high rainfall in the pre-monsoon season allowed increased breeding of mosquitoes leading to an early and consequently large outbreak in the county.

Dhaka is one of the most densely populated cities in the world with more than 22 million people living in approximately 300 square kilometers with a population density of 23,234 people/KM2 17. Many people travel to their rural homes during two large festivals: Eid-Al-Fitr and Eid-Al-Adha. In 2023, the Eid-Al-Adha was celebrated on 28th June. Up until 28th June 2023, a total of 7862 patients were recorded in the country of which 6014 (76.5%) were recorded in the capital city. More than 15 million people left Dhaka and its surrounding cities to celebrate Eid-Al-Adha with their families in rural Bangladesh18. This large movement probably played a role in spreading the DENV throughout the county. People infected with DENV can remain viremic (infectious) for a maximum of 12 days 19. Although *Aedes* *aegypti*, the key vector of DENV transmission is a city-adapted mosquito, *Aedes albopictus,* is adapted more to rural settings. Earlier studies in Bangladesh reported the presence of *Aedes albopictus* in different parts of Bangladesh 6,20. In 2023, infected people traveling from Dhaka to rural areas may have spread the virus to the rural areas where the *Aedes albopictus* mosquito maintained the local transmission 21. The earlier start of the monsoon in 2023 (ref) also coincided with this and further influenced the growth of the vector population in the rural areas22. By 25 July 2023, all 64 districts reported at least one DENV infection in their hospitals. In that specific time, a total of 37, 688 patients were recorded in the country of which 22349 (59.30%) were recorded in the capital city. The spreading of DENV across the country might have severe consequences for the ongoing outbreak and the coming years. The rural cycle of DENV transmission is usually led by *Aedes albopictus* and there is some specific difference that makes *Aedes albopictus* a crucial vector for DENV.

This is interesting to see that districts of southern parts of Bangladesh have a higher incidence of dengue cases in 2023. Although Bangladesh is a small country there are some differences between the southern and northern parts of Bangladesh as districts in the southern parts observe a higher rate of urbanization and high population density. Also, the Divisions in the south of Dhaka has 0.92 °C higher temperature (27.46 vs 26.54 °C, p<0.01) but 633 mm lower rainfall (2643 mm vs. 2010, p<0.01) compared to the Divisions divisionsin the north to Dhaka. However, it might be possible that a higher incidence of dengue cases in southern districts is an artifact of economic development in the regions which helped people visit healthcare facilities more frequently than their northern counterparts. Our model also showed that the ratio of urban and rural population which we used as a proxy to indicate urbanization had a higher risk of having more dengue cases. More research is needed to confirm the reason for the higher incidence of dengue cases in southern parts of Bangladesh.

The case-fatality rate observed in 2023 is 10 times higher than WHO’s goal to limit the dengue-related CFR below 0.05% 23. The CFR of primary DENV infection is generally low with an estimated value of 0.01-0.1%, but the CFR could reach up to 1-4% for secondary or tertiary DENV infection. In the past 23 years, Bangladesh recorded a CFR of 0.34% which is high compared to other countries in the region 1. In 2023, the CFR is much higher (0.53%) which is inflated by a very high fatality rate in the capital city Dhaka (0.88%). The high CFR in Dhaka city can be explained as a possible higher rate of secondary or tertiary cases as more than 80% of people in Dhaka city were exposed to any one serotype of DENV in the past 6. Moderate to severe cases outside of Dhaka city have been referred and travelled/travelled to hospitals in Dhaka for better health care, especially for ICU needs. WHO’s situation report reveals that 41% of the death cases were referred to larger cities, especially Dhaka 24. More than 44% of patients with DENV infection admitted to hospitals in Dhaka city were from outside Dhaka 21. Also, there is a more regular and organized notification of deaths from Dhaka city as compared to other parts of the country where deaths might be underreported especially when occurred in private health care facilities. Bangladesh dengue surveillance is only based on selected hospital admissions which account for approximately 5% of total hospitals in the county, and the patients outside these hospitals as well as private clinics and those not attending any health care settings are not included. 21 Thus, the current passive surveillance system might underreport a substantial number of patients in the denominator of the CFR estimation. However, moderate and severe patients are likely to be admitted in hospitals and thus the deaths are more likely to be notified as compared to the the overall infected cases. Thus, it might be worth mentioning that the CFR that we are reporting is more of a CFR for moderate and severe dengue cases, as the denominator might miss a substantial proportion of non-severe dengue cases.

Until the reappearance of DENV-serotype 3 in 2019, the DENV virus was mostly endemic in urban settings with a large portion of people being exposed to the virus in their lifetime 6. The distribution of *Ae. aegypti* which is an urban-dwelling mosquito probably played a role in such high seroprevalence 6. This high seroprevalence in the large cities, especially in metropolitan Dhaka created the opportunity for exposure to second, third, or fourth infection with heterogenous serotypes. The top five districts with higher CFR for DENV infection are Faridpur (1.84%), Barisal (1.23%), Dhaka (0.87%), Chittagong (0.75%) and Tangail (0.69%). All four serotypes of the dengue virus have been recorded in Bangladesh at different times since 2000. DENV- Serotype 3 caused a larger outbreak in 2019 and remained a dominant serotype until 2022. DENV-4 reappeared in the year 2022 with co-circulation of DENV-1 and DENV-3. In 2023, DENV-2 became a predominant serotype (62%) along with DENV-3 (29%) and co-infection of DENV-2 and DENV-2 (10%) 25. Thus, exposure to heterogenous serotypes increases the risk of severe dengue infection due to secondary and/or tertiary dengue infection which has a much higher CFR than the primary infection 19. The number of reported cases in a different district in Bangladesh is correlated with the population size (r=0.76, p<0.001) of the district**.**

**Conclusion:**

Bangladesh’s 2023 dengue outbreak is characterized by a higher incidence of dengue cases in the southern districts of the country. In contrast to the historical epicentre in the metropolitan capital city Dhaka, the 2023 outbreak resulted in a significant number (65%) of cases recorded from outside Dhaka. The spreading of cases was facilitated by urbanization as indicated in the proportion of urban vs rural people, and a higher temperature and rainfall in the southern districts. In general, there was an early onset and surge of dengue cases in the capital city Dhaka with an earlier rainfall in March (90 mm) and the possible spreading of the virus during Eid-Al-Adha, the largest Muslim religious festival in the country. A higher proportion of deaths were recorded in the capital city Dhaka which might be associated with increased secondary infection in the city as well as care seeking of severe dengue cases from all around the country to the capital city hospitals.country. Bangladesh needs short-, medium-, and long-term plans to control or at least alleviate the burden of dengue-related cases and deaths in the country. Finally, long-term planning is essential to address the event of unusual rainfall which extends vector season in the country.

**Conflicts of interest:** The authors declare no conflict of interest.

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**Ethics statement:** We used data that are publicly available in the daily press release of the Ministry of Health and Family Welfare (<https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report> ). There is no individual-level data and thus ethical approval is not required.

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**Appendix 1: Table** The relative changes of Dengue cases in each division in Bangladesh, 2023. Although Dhaka city remains the center of the outbreak, the percentage of cases has increased outside Dhaka city after July 2023.

|  |  |  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Divisions | No cases in Jan | Relative increase in Feb (%) | Relative increase in Mar (%) | Relative increase in Apr (%) | Relative increase in May (%) | Relative increase in June (%) | Relative increase in July (%) | Relative increase in Aug (%) | Relative increase in Sep (%) | Relative increase in Oct (%) | Relative increase in Nov (%) | Relative increase in Dec (%) |
| Dhaka city | 272 | 46.11% | 66.96% | 64.58% | 83.41% | 78.93% | 52.72% | 40.04% | 31.66% | 23.53% | 21.29% | 23.39% |
| Dhaka division (Except Dhaka city) | 58 | 10.18% | 2.68% | 2.08% | 3.09% | 3.36% | 11.10% | 16.39% | 19.26% | 23.05% | 22.99% | 21.95% |
| Mymensingh | 7 | 1.80% | 1.79% | 1.39% | 1.25% | 1.61% | 2.68% | 3.16% | 2.65% | 2.02% | 2.29% | 3.14% |
| Chittagong | 140 | 23.95% | 16.07% | 23.61% | 7.91% | 8.11% | 13.36% | 14.98% | 15.13% | 13.22% | 11.24% | 15.36% |
| Khulna | 24 | 4.19% | 4.46% | 3.47% | 0.77% | 1.98% | 3.97% | 6.27% | 10.32% | 15.64% | 19.49% | 16.88% |
| Rajshahi | 7 | 0.60% | 0.89% | 0.69% | 0.10% | 0.45% | 2.33% | 4.32% | 5.52% | 8.60% | 10.49% | 8.16% |
| Rangpur | 2 | 0.60% | 0.89% | 0.69% | 0.10% | 0.47% | 1.85% | 2.40% | 1.68% | 1.53% | 1.13% | 1.57% |
| Barisal | 53 | 16.77% | 12.50% | 8.33% | 3.95% | 4.58% | 11.12% | 11.75% | 13.46% | 12.18% | 10.95% | 9.44% |
| Sylhet | 3 | 0.60% | 0.89% | 0.69% | 0.19% | 0.64% | 0.88% | 0.71% | 0.32% | 0.24% | 0.16% | 0.18% |