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

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**Abstract (word count: 280, target 250).**

**Background:** In 2023, Bangladesh experienced its largest and deadliest outbreak of Dengue virus (DENV), reporting the highest-ever recorded annual cases and deaths caused by Dengue Fever. We aimed to characterize the geographical transmission dynamics of the DENV in Bangladesh.

**Methods:** From 1 Jan – 31 Dec 2023, we extracted and analyzed data on Dengue from the Management Information System (MIS) of the Ministry of Health and Family Welfare. Temperature, rainfall, and relative humidity data were collected from the Bangladesh Meteorological Department. The urban-rural ratio, population density, and distance from Dhaka were taken into account alongside meteorological data to assess the geographical distribution and were evaluated using a generalized linear mixed model.

**Findings:** The number of Dengue cases reported in 2023 was 1.3 times higher than the total number recorded in the past 23 years: 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). Of the 1705 people who died in 2023, 67.4% (n=1015) died within one day after hospital admission, with a mean hospital stay of 2.5 days (range: 0-61 days). The divisions southern to Dhaka had a higher dengue incidence compared to the northern division (2.30 vs. 0.50, p<0,0.01), whereas the central Dhaka division had an incidence of 2.90 per thousand population. Meteorological data suggested that the southern divisions also had higher mean annual temperatures than the northern division (27.46 vs. 26.54 °C) in 2023. The urban and rural population ratio of the divisions (IRR: 1.04, 95% CI: 1.03-1.04), temperature (IRR: 1.13, 95% CI: 1.11-1.14) showed positive, and rainfall (IRR: 0.99, 95% CI: 0.98-0.99) showed negative association with dengue cases in each division.

**Interpretation**: We observed a major geographical shift of Dengue cases from the capital city Dhaka to different districts of Bangladesh with a higher incidence of cases in the southern division of Bangladesh, possibly influenced by temperature and rainfall. Policymakers should address this shift and its relationship with meteorological factors in their comprehensive actions.

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**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 ratio of 0.49% 1. In 2023 the number of dengue cases (321,179) and deaths (1705) surpassed these figures 2. While this number is shocking and concerning, epidemiologically, these figures are not unexpected based on the recent 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 Bangladesh have been reported in urban areas, with a particular concentration in the capital city of Dhaka 3 except in some years (e.g., 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, Chattogram, 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 Chattogram 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 and fatalities in variable geographic regions. Of 320,835 cases, 207,716 (65%) were reported from outside Dhaka, whereas more than 57.5% (980 of 1705) deaths were recorded in Dhaka.

Due to the varying dynamics of dengue vectors and their interactions with several environmental factors, very little is known regarding the spread and causes of dengue disease. Yet there are several attempts found in the literature [Our previous papers].

*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 to quantify the factors affecting the dispersion of dengue cases in Bangladesh.

**Methods:**

**Source of the data:** We collected the publicly available data on all dengue cases and 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 (<https://old.dghs.gov.bd/index.php/bd/home/5200-daily-dengue-status-report> ). 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/or nonstructural 1 protein (NS-1) of DENV 10. MIS collected data from the hospitals that reported dengue cases and which reported 77 hospitals based in Dhaka city (20 public and 57 private hospitals) and the district hospitals of 63 other districts of the country including the hospitalized patients in tertiary care medical college hospitals 11. We collected 3-hourly meteorological data for temperature, and daily rainfall from the Bangladesh Meteorological Department (BMD) over the period 2000–2023 from the meteorological station located in divisional headquarters including Agargaon, Dhaka (Lat 23.46, Lon 90.23), Chattogram (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). We drew 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). As the Dhaka division is centrally situated in Bangladesh, it was excluded from the southern or northern part.

**Patient data:** We further collected individual patient data including age, sex, address, and hospital stays from MIS. We plotted the age and gender-wise distribution of cases. We also summarized the hospital stays of the death cases. Hospital stays for the survival cases were not available.

**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 of dengue cases for a month were estimated with the formula as shown below

where *RCt*is the relative changes ofof 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 district-wise incidence of dengue cases in 2023. We compared the incidence by divisions (southern vs. northern).

**Statistical Analysis**

We compared the dengue cases and deaths of the year 2023 with the previous 23 years (2000-2022), prepared graphs, plots, and maps, and compared these data with meteorological parameters. We reshaped our dataset by incorporating division-wise outcome variables. We followed the list of districts for each division as shown in the daily dengue situation report shared by MIS 2. We further collected division-wise population and geographical data from the Statistical Yearbook Bangladesh 2022 published by the Bangladesh Bureau of Statistics 12 including population size, the ratio of rural and urban population (which is a proxy variable for urbanization), and distance from the capital city, Dhaka. Additionally, we calculated population density by dividing the population size by the area of each division district.

We used 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 13. We introduced the random effect into the GLMM model to account for the time series effects in the data.13. The choice of negative binomial distribution allowed us to model response data appropriately with extra-variations into the data (overdispersion) 14. Parameter estimation in GLMMs is challenging due to the integration of random effects in the likelihood function 15. 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* 16.

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:**

**Dengue Cases**

During 2023 (1 Jan to 31 December), a total of 321,179 dengue cases have been reported with 1,705 deaths (case fatality ratio 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: 2000-2022, (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 individuals with 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 of Dhaka including 980 deaths (case-fatality ratio: 0.89%) and 211,171 cases were reported from outside Dhaka including 725 deaths (case-fatality ratio of 0.34%). A higher proportion of cases were detected among young adults of <30 years [55 vs. 45%] but a greater proportion of deaths were detected among older adults of >30 years (68 vs 32%) **(Fig S1)**. Although males constituted a higher percentage of cases (60 vs 40%), females constituted a greater proportion of deaths(57 vs. 43%) **(Fig S2).**



**Fig 1:** The total number of dengue cases and deaths reported in each month 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.

Of the 1,705 people who died in 2023, 67.4% (n=1,015) died within one day after hospital admission, with a mean hospital stay of 2.5 days (range: 0-61 days). While considering the first 2 days, the death toll increased to 74.6% (n=1273) or 81.9 % (n=1397) in the first 2 days **(Fig 2)**.

A graph with numbers and a bar

Description automatically generated

**Fig 2:** The number of days of hospital stays of 1705 dengue cases in Bangladesh: 1 Jan – 31 Dec 2023. More than 67% (n=1015) of people died within one day of hospital admission.

**Meteorological Data**

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 3)**. 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 only marginally to 27.06 °C in 2023 **(Fig 3)**.

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**Fig 3:** The rainfall (mm) and temperatures (°C) of Bangladesh as recorded in a weather station in Agargaon, Dhaka, by Bangladesh Meteorological Department, Bangladesh for the period 2000-2022 vs. 2023.

**Meteorological data and dengue cases in Southern vs. Northern Divisions**

The divisions southern to Dhaka had a higher dengue incidence compared to the northern division (2.30 vs. 0.50, p<0,0.01) whereas the central Dhaka division had an incidence of 2.90 per thousand population. The southern divisions also had significantly higher annual temperatures than the northern division (27.46 vs. 26.54 C) in 2023.

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Parameters** | **Southern Divisions** | **Northern divisions** | **p-value** | **Dhaka Division** |
| Annual mean temperature (°C) in 2023 | 27.46 | 26.54 | <0.01 | 27.07 |
| Annual total rainfall (mm) in 2023 | 2026.5 | 2638.13 | 0.049 | 2160.7 |
| Incidence of dengue (per 1000 population) | 2.30 | 0.50 | <0.01 | 2.92 |
| Case-fatality ratio of dengue (%) | 0.24 | 0.13 | 0.110 | 0.29 |

**Table 2:** The incidence and case-fatality ratio of dengue and annual temperature and rainfall in 2023 in the Southern and Northern divisions of Bangladesh

**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 Chattogram division have been among the prominent sites of the outbreak **(Fig 4)**. 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 4).** 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 4)**. 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 divisions (p<0.01). The mean annual temperature recorded in the southern divisions 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 4:** 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 (**Fig 5)**. 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 5:** 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 number of dengue cases at 113,233, followed by Chattogram (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). For the number of dengue-related deaths, Dhaka reported the highest death toll at 981, trailed by Barisal (167), Faridpur (138), Chattogram (106), and Khulna (41) district **(Fig 6)**.



**Fig 6: 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). 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 incidence (2.30 vs. 0.50) and case-fatality ratio (0.24 vs. 0.13) of dengue cases than the northern divisions. The southern division also had a higher annual mean temperature (27.46 vs 26.54 °C) compared to the northern divisions 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 7)**.



**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 average relative humidity of the division (IRR: 1.09, 95% CI: 1.08 – 1.09). Daily total rainfall of the division (IRR: 0.99, 95% CI: 0.98-0.99), showed a significantly negative association between dengue cases. Population density and distance from Dhaka also exhibited weak negative associations **(Table 3)**.

**Table 3: 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 |

**Discussion:**

This is the first up-to-date study to characterize the geographical transmission dynamics of the DENV in Bangladesh. In addition to a very high number of dengue cases and deaths, Bangladesh’s 2023 dengue outbreak shows some unique characteristics including i) a widespread distribution of cases nationwide outside Dhaka, ii) a large proportion of deaths (67%) recorded within the first 24 hours of hospital admission, iii) a very high case-fatality ratio of dengue cases within capital City Dhaka, and iv) a higher incidence of dengue cases in the southern divisions of Bangladesh.

Several drivers could have contributed to the largest outbreak of dengue fever in Bangladesh. First, the dengue serotype -2 (DENV-2) reappeared in Bangladesh after 2018 17. The absence of the serotype allowed a large proportion of the population to be immunologically naïve as the city experienced more than 4.4% annual growth of population 18. Second, the outbreak in 2022 with a relatively warmer year and persisting rain later in the year continued to 2023 17. 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) 17. Third, high rainfall in the pre-monsoon season in 2023 (90 mm in March) allowed increased breeding of mosquitoes leading to an early and consequently large outbreak in the county.

A large majority of deaths (67%) occurred within the first day of hospital admission, suggesting severe disease and/or a considerable delay in seeking medical care. The precise cause of these deaths warrants thorough investigation. Below, we outline two possible explanations for this delay in seeking hospitalization. First, numerous patients arrived at the hospital only at the eleventh hour. While primary dengue infection tends to be mild and self-limiting, subsequent infection may escalate to severe forms due to antibody-dependent enhancement and other unknown mechanisms 19. Distinguishing between primary and subsequent dengue infection is often challenging. Hence, we advocate for the documentation or self-preserving of dengue test results in regions where heat data is not recorded systematically.

Second, a significant portion of dengue patients (44%) 20 travelled to Dhaka from areas outside the capital city for treatment. These individuals either sought medical attention at a critical stage or were transferred after spending several days admitted to hospitals in districts or sub-districts, with those initial days not being counted as part of their final hospital admission. Many of these patients endangered their lives by undertaking long journeys to Dhaka without access to intravenous fluid during travel.

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 21. 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 Bangladesh22. This large movement probably played a role in spreading the DENV throughout the county. People infected with DENV can remain viraemic (infectious) for a maximum of 12 days 23. 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 6,24. 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 20. The earlier start of the monsoon in 2023 also coincided with this and further influenced the growth of the vector population in the rural areas25. 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 22,349 (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. The *Aedes albopictus* mosquito can bite non-human hosts, tends to bite outdoors, and breeds in tree holes and other natural settings which gives them better plasticity than *Aedes aegypti* 26.

The southern divisions of Bangladesh had a higher incidence and CFR 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 had 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 in 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 27. 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. Further research is needed to confirm the reason for the higher incidence of dengue cases in southern parts of Bangladesh.

The case-fatality ratio (CFR) observed in 2023 is 10 times higher than World Health Organization’s (WHO) goal to limit the dengue-related CFR below 0.05% 28. 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 29. 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 ratio 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 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 30. More than 44% of patients with DENV infection admitted to hospitals in Dhaka city were from outside Dhaka 20. 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 dengue cases are admitted in the 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. 20 Thus, the current passive surveillance system might underreport a substantial number of patients in the denominator of the CFR estimation. However, patients with moderate and severe disease are likely to be admitted in hospitals, and thus, the deaths are more likely to be notified as compared to 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 endemic primarily in urban settings, with a large portion of people being exposed to the virus in their lifetime 6. The distribution of *Aedes aegypti*, which is an urban-dwelling mosquito, probably played a role in such high seroprevalence 6. This high seroprevalence in large cities, especially in metropolitan Dhaka, created the opportunity for exposure to second, third, or fourth infection with heterogenous serotypes 31. All four serotypes of the dengue virus have been recorded in Bangladesh at different times since 200017,31. 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%) 32. 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 23.

**Limitation:** The current dengue cases and deaths have been recorded through hospital-based passive surveillance in Bangladesh. The surveillance covers a mere fraction (5%) of the country’s total health healthcare facilities 20. While we observed significant differences in dengue incidence and CFR between the southern and northern divisions, potential biases linked to the passive surveillance method cannot be ruled out. While improbable, there’s a chance that district health officials in the southern division may have reported more diligently than those in the northern divisions.

**Conclusion:**

The 2023 dengue outbreak in Bangladesh is marked by an increased occurrence of dengue cases in the southern divisions, with cases spreading geographically from the capital, Dhaka, to other parts of the country, with a notable 65% of cases reported from areas outside Dhaka. The transmission of dengue cases was facilitated by urbanization, as indicated in the proportion of urban vs rural population, and a higher temperature in the southern districts. A large proportion (67%) of deaths were recorded within one day of hospitalization, indicating a late admission of patients with severe disease. In general, there was an early onset and surge of dengue cases in the capital city, Dhaka, with an earlier total 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 or care seeking of severe dengue cases from all around the country to the capital city hospitals. Bangladesh needs active case and death surveillance, and vector surveillance that incorporates meteorological data and research to identify the causes of increased deaths for improved dengue care. Improved estimation of subclinical cases, their associated risk factors, and temporal trends are vital for informing policy and monitoring the efficacy of public health interventions. Despite existing gaps in knowledge, the significant scale of the issue underscores the need for immediate attention by raising awareness campaigns.

**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 are no identifiable individual-level data, and ethical approval is not required.

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**S1: The age structure of dengue cases during 1 Jan-31 Dec 2023 in Bangladesh. A higher proportion of cases were detected among young adults (<30 years) [55% vs. 45%] but a greater proportion of deaths were detected among older adults (>30 years) (68% vs. 32%).**

A green and blue bars

Description automatically generated

**S2: The comparison of the proportion of dengue cases and deaths in 2023 in Bangladesh by gender. Although Males constitute a higher percentage of cases, females constitute a greater proportion of deaths.**

A blue and green pie chart

Description automatically generated