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Epidemiology, Trends, Risk Factors, and Clinical Outcomes of Dengue Fever among Adolescents and Young Adults in Dhaka City of Bangladesh

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Abstract

Background: Dengue fever is an escalating public health concern in Bangladesh, with Dhaka City experiencing recurrent epidemics that disproportionately affect adolescents and young adults. **Objective:** This study was aimed to analyse fourteen years of surveillance data to characterize demographic, socioeconomic, and seasonal determinants of dengue morbidity and mortality in this vulnerable population. **Methodology:** A retrospective, record-based design was applied using hospital surveillance data and Directorate General of Health Services (DGHS) databases from January 2010 to November 2023. All laboratory-confirmed cases were included based on national diagnostic criteria (NS1 antigen, IgM, or RT-PCR). Data were compiled, cleaned, and analyzed using descriptive statistics to summarize demographic patterns, while chi-square tests and logistic regression examined associations between age, sex, socioeconomic status, residential setting, and severity. Correlation analysis assessed seasonal effects of rainfall. **Results:** Approximately 117,000 confirmed cases were identified. The mean age was 18.7 years (SD ± 2.1); late adolescents (18 to 20 years) comprised 46.0% of cases, with males accounting for 55.0%, though females showed 15.0% higher hospitalization and complication rates ($p < 0.05$). Low-income youth experienced 30% higher prevalence, while those in informal settlements had 1.4-fold greater odds of infection (95% CI: 1.2–1.7). First-time infections accounted for 84.0% of cases, while recurrent infections nearly doubled the odds of severe dengue (OR 1.92; 95% CI: 1.55–2.38). Annual epidemics peaked in 2019 (101,354 cases, 179 deaths), 2022 (62,382 cases, 281 deaths), and 2023 (69,483 cases, 327 deaths), with CFR rising to 0.47%. Monsoon months showed a 50.0% to 60.0% increase in cases, strongly correlated with rainfall ($r = 0.71$, $p < 0.001$). **Conclusion:** Adolescents in Dhaka city face disproportionate dengue risks shaped by social inequities, recurrent infection, and seasonal climate variation. Future studies should evaluate behavioral, nutritional, and immunological determinants in greater depth, while public health efforts prioritize youth-focused education, strengthened healthcare capacity, and climate-sensitive surveillance to mitigate rising severity. [*Bangladesh Journal of Infectious Diseases, June 2025;12(1):3-17*]

Keywords: Dengue fever; viral transmission; adolescents; young adults; seasonal variation; epidemiology; Dhaka City

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Introduction

Dengue fever has become a pressing public health issue in Bangladesh, particularly in Dhaka City, which has emerged as the epicenter of recurrent outbreaks. The city's dense population of more than 10 million people, coupled with rapid and unplanned urbanization, limited waste management, and favorable climatic conditions, provides an ideal setting for the proliferation of *Aedes aegypti*, the primary mosquito vector of dengue virus (DENV). According to the Directorate General of Health Services (DGHS), Bangladesh experienced its highest recorded outbreak in 2019, with over 101,000 laboratory-confirmed cases and 179 deaths nationally, the majority concentrated in Dhaka[1]. More recently, the country faced an unprecedented surge in 2023, with more than 300,000 reported cases and over 1,600 deaths, representing the deadliest dengue outbreak in its history[2]. These statistics highlight not only the growing severity of dengue in Bangladesh but also the disproportionate burden faced by urban residents, particularly adolescents and young adults.

Dengue fever, a major arboviral disease, remains one of the most significant global public health concerns. The World Health Organization (WHO) estimates that nearly half of the world's population is now at risk of dengue, with approximately 100 to 400 million infections occurring annually worldwide. In Southeast Asia, Bangladesh ranks among the countries most severely affected, alongside Thailand, the Philippines, and Indonesia. The recurrent epidemics in Dhaka are strongly linked to seasonal monsoon patterns—characterized by heavy rainfall, high humidity, and persistent waterlogging—which create optimal breeding habitats for *Aedes* mosquitoes[3]. Between August and October each year, dengue incidence in Dhaka typically peaks, with studies reporting a 50.0 to 60.0% higher case load during these months compared to the dry season.

The epidemiology of dengue in Bangladesh also reflects a concerning shift toward severe clinical outcomes and an expanding demographic impact. Historically, children were considered the most vulnerable group for dengue infection; however, recent evidence indicates that adolescents and young adults (15 to 22 years) are increasingly susceptible[4]. Several factors may account for this trend, including frequent outdoor exposure, school and university attendance in high-density environments, and lower adherence to preventive measures. Recent seroprevalence studies in Bangladesh reveal that nearly 70.0% of urban adolescents show past exposure to the dengue virus, underscoring the scale of silent transmission. Additionally, gender-based analyses suggest that while young males have slightly higher infection prevalence, females often experience greater severity and hospitalization rates[5]. In addition to dengue, Bangladesh and other South Asian countries have reported the concurrent circulation of influenza affecting an estimated 10.0% to 15.0% of the population annually, emerging outbreaks of monkeypox virus[6] with more than 95,000 cases globally since 2022 and ongoing rubella–congenital rubella virus (RCV) clusters, underscoring the multifaceted infectious disease burden that overlaps and complicates dengue prevention and response efforts[7]. Several surveys during the COVID-19 pandemic in Bangladesh revealed that university students experienced a dual burden, with rising dengue incidence—over 28,000 confirmed cases nationwide in 2021—occurring alongside COVID-19 outbreaks[8], amplifying psychosocial distress through fear of co-infection, academic disruption, and heightened anxiety and depression reported in more than 40.0% of students[9].

Despite ongoing public health efforts—such as community awareness campaigns, fogging operations, and hospital preparedness—the dengue burden continues to escalate. Several critical barriers have limited the effectiveness of interventions in Dhaka. These include inconsistent vector control, inadequate coordination between municipal and health authorities, limited use of digital surveillance tools, and socio-economic disparities that restrict access to timely healthcare. Studies also highlight how residents of informal settlements face infection rates up to 40.0% higher than those in formal housing areas, reflecting the role of inequities in shaping disease vulnerability[10]. The overlap of the COVID-19 pandemic with recurrent dengue outbreaks in Bangladesh has further strained the healthcare system, compounding both the physical burden of co-infection and the mental health distress associated with uncertainty, delayed care, and limited resources[11]. The growing challenge of antimicrobial resistance (AMR), with recent reports showing that resistant bacterial infections account for an estimated 90,000 childhood deaths annually in South Asia[12,22], further complicates dengue management by limiting treatment options for secondary infections and increasing the overall vulnerability of children to severe outcomes[13].

In recent years, regional and global research has expanded our understanding of dengue transmission dynamics. Spatial analyses have identified Dhaka as the most concentrated hotspot of persistent dengue clustering across Bangladesh[14]. Climate-based modelling further demonstrates strong associations between rainfall variability, temperature fluctuations, and case incidence, underscoring the climate-sensitive nature of dengue epidemics[15]. Air pollution and recurrent respiratory infections, intensified by broader climate change challenges such as rising temperatures and erratic rainfall, further exacerbate dengue vulnerability by weakening population health and creating ecological conditions favorable to mosquito proliferation[16]. While these studies provide valuable insights into macro-level drivers, there remains a notable gap in understanding the micro-level vulnerabilities of urban youth populations, who now account for a growing proportion of cases but remain understudied as a specific demographic[18,19]. Existing literature has not sufficiently examined how socio-economic background, education, gender, and healthcare access intersect to shape dengue risk in adolescents and young adults. Moreover, limited evaluations have been conducted on the efficacy of youth-targeted interventions, such as school-based awareness programs or digital health tools, despite their potential to transform prevention strategies.

This study aimed to address the existing gap in dengue research by focusing specifically on adolescents and young adults (15 to 22 years) in Dhaka City across a fourteen-year period (2010 to 2023), with particular emphasis on the unprecedented outbreak in 2023. By integrating community survey data with hospital and surveillance records, it sought to provide a detailed assessment of the demographic, socioeconomic, and environmental determinants that shaped dengue risk in this age group. The objectives were to quantify age- and sex-specific burdens of disease, examine the influence of socioeconomic status and residential setting, and evaluate the impact of educational and public health interventions on outcomes. Through this comprehensive approach, the study aimed to generate evidence that not only advances understanding of dengue dynamics among youth in Bangladesh but also informs the design of targeted, sustainable strategies for dengue prevention and control in other high-risk urban contexts globally.

Methodology

Study Design and Setting: This study was conducted as a retrospective, record-based secondary analysis of routinely collected dengue surveillance data and hospital records. The analysis covered the period from January 2010 through November 2023, allowing for evaluation of both annual trends and seasonal variations, as well as the inclusion of years with major national outbreaks such as 2019 and 2023. The setting was Dhaka City, the capital of Bangladesh, which is home to more than ten million residents and is recognized as the epicenter of recurrent dengue epidemics in the country. Dhaka is a rapidly urbanizing megacity characterized by high population density, inadequate waste management, irregular water supply, and large informal settlements, all of which facilitate the proliferation of Aedes aegypti, the principal vector of dengue virus. The city has a humid subtropical monsoon climate, with heavy rainfall and high relative humidity during the months of August to October, creating peak conditions for mosquito breeding and transmission. These climatic and demographic features provided the rationale for examining both long-term epidemiological trends and seasonal peaks in dengue transmission. The study focused specifically on adolescents and young adults aged 15 to 22 years, who represent a demographic increasingly shown to be at elevated risk for dengue infection due to their social mobility, outdoor exposure, and concentration in educational and densely populated residential environments.

Data Sources: Three complementary sources were integrated to construct the analytic dataset. First, annual hospital surveillance files were retrieved from major public and private tertiary facilities in Dhaka that perform laboratory confirmation of dengue and maintain outcome registers. Second, aggregated city-level counts of laboratory-confirmed cases and dengue-related deaths were obtained from the Directorate General of Health Services (DGHS), Communicable Disease Control unit, which collates reports from sentinel hospitals and laboratories. Third, World Health Organization (WHO) Bangladesh situation reports, and annual summaries were used for external validation and reconciliation of totals. These sources were selected because they are routinely maintained, cover the full study period, and include laboratory confirmation indicators required by national case definitions.

Study Population and Eligibility Criteria: The target population comprised adolescents and young adults aged 15 to 22 years who were residents of Dhaka City and were recorded as laboratory-confirmed dengue cases during the study period. Inclusion required (i) age 15 to 22 years at diagnosis, (ii) residence within the administrative boundaries of Dhaka City, and (iii) laboratory confirmation according to national diagnostic guidance in force for the respective year. Exclusion criteria were applied to remove records with missing or unverifiable age or residence, entries without laboratory confirmation, clear duplicates across data sources, and purely clinical/suspected cases that lacked confirmatory testing. Because the objective was to enumerate the full burden in this demographic, no sampling was performed; the analysis treated all eligible records as a census of available cases.

Case Definitions: A confirmed dengue case was defined as an acute febrile illness with laboratory evidence of dengue virus infection established by one or more of the following: *NS1* antigen positivity, dengue-specific *IgM* serology, or reverse-transcription polymerase chain reaction (RT-PCR) performed in hospital or accredited laboratories, consistent with national surveillance definitions used by DGHS for notification. A dengue-related death was defined as death occurring in a laboratory-confirmed dengue patient during the index illness, recorded in hospital outcome registers and appearing in DGHS mortality tallies for the same time frame. Uniform definitions were applied retrospectively across all years to maximize comparability despite gradual expansion of diagnostic capacity over time.

Case Identification, Selection, and Search Strategy: Eligible cases were identified through a structured, sequential process. Hospital annual epidemiology reports and electronic registers were first enumerated and digitized to standardized templates. City-level DGHS aggregates were then obtained for the same calendar years and used to cross-check hospital totals. Where discordance was detected, reconciliation favored records with explicit laboratory confirmation and verified outcomes. WHO Bangladesh reports served as an independent benchmark to flag potential under-ascertainment during peak seasons; when discrepancies exceeded predefined tolerance (±2.0% for totals), counts were re-verified with source hospitals. This multi-source triangulation minimized duplication and underreporting and established a consistent final series.

Data Compilation and Quality Assurance: All source files were imported into a master database and harmonized to common variable names and formats. Deterministic linkage keys (hospital, year, anonymized patient code, age, sex, test type, result date) were used to identify and remove duplicates across sources. Implausible values (e.g., age outside 15–22, death before diagnosis date) triggered record-level review; unverifiable entries were excluded. Demographic fields were standardized to prespecified categories (age bands 15–17, 18–20, 21–22; sex male/female; residence strata where available). A three-step audit (range checks, logic checks, and external reconciliation against DGHS/WHO totals) was performed for each year before lock.

Variables and Measures: Primary endpoints were annual counts of laboratory-confirmed dengue cases and dengue related deaths among 15 to 22 year olds. From these, the annual case-fatality rate (CFR) was calculated as (deaths ÷ confirmed cases) × 100, with exact binomial 95% confidence intervals. Secondary measures included seasonal distribution (monsoon: August–October vs non-monsoon months), age-band distribution (15 to 17 years, 18 to 20 years, 21 to 22 years), sex distribution, and, where available, residential context like formal housing, informal settlements, peri-urban. Laboratory modality (NS1, IgM, RT-PCR) was captured when present to describe confirmation patterns over time. Because this is a secondary analysis of routinely collected surveillance, clinical severity markers were not uniformly available and were not prespecified outcomes.

Handling of Missing Data: Records missing essential eligibility fields (age, residence, or laboratory confirmation) after attempted verification were excluded from analysis. For descriptive stratifications (e.g., sex) with partial missingness, denominators were reported explicitly for each stratum. No imputation was performed for primary outcomes (cases, deaths) or for the CFR, given their aggregate nature and the triangulation-based reconciliation.

Bias, Confounding, and Sensitivity Analyses: Potential biases include under-ascertainment during surge periods, variation in testing access over time, and misclassification of cause of death. To mitigate these, the study reconciled hospital, DGHS, and WHO series; prioritized laboratory-confirmed notifications; and applied uniform case definitions across years. Sensitivity analyses assessed robustness of trends by (i) recalculating annual CFRs using hospital-only denominators, (ii) restricting to years with complete laboratory modality recording, and (iii) excluding months with documented reporting disruptions, to evaluate the influence of surveillance artifacts on temporal patterns.

Statistical Analysis: All analyses were performed using IBM SPSS Statistics, version 29.0 and Stata, version 18.0. Descriptive summaries reported annual counts, deaths, CFRs, and demographic distributions. Temporal trends in incidence and mortality were examined using non-parametric tests for trend across ordered groups and visualized with year-by-year line plots. Seasonal effects were evaluated by comparing monsoon versus non-monsoon counts using chi-square tests and by estimating monsoon proportion with 95% confidence intervals. Sex and age-band differences were assessed with chi-square tests of independence; where appropriate, Cochran–Armitage tests for trend were applied across ordered age bands. All tests were two-sided with $\alpha = 0.05$. Graphical diagnostics were used to inspect outliers and year-specific anomalies; when observed, underlying source tables were re-checked against DGHS and WHO aggregates before finalization.

Ethical Considerations: Ethical approval for this retrospective secondary analysis was granted by the National Institute of Neurosciences (NINS), Dhaka, Bangladesh. Formal permission was obtained from participating hospitals to use de-identified surveillance records, and authorization was granted to access aggregated dengue databases from DGHS. The analysis used anonymized, aggregate data only; individual consent was not required. Data handling complied with national regulations and international standards for confidentiality and responsible secondary use of health information.

Reporting Standards: This study adheres to the STROBE recommendations for observational studies. Definitions, eligibility criteria, data sources, handling of missing data, and analytical methods are reported to facilitate transparency and reproducibility

Results

Demographic Characteristics of the Study Population: The demographic characteristics of the study population are summarized in Table 1. Over the fourteen-year period from January 2010 to November 2023, approximately 117,000 laboratory-confirmed dengue cases were identified among adolescents and young adults aged 15 to 22 years in Dhaka City. The mean age at diagnosis was 18.7 years (SD ± 2.1), with late adolescents aged 18 to 20 years comprising the largest affected subgroup, followed by those aged 15 to 17 years and 21 to 22 years. A slight male predominance (55.0% *vs.* 45.0%) was observed; however, females consistently experienced higher rates of hospitalization and severe clinical outcomes. Socioeconomic differences were evident, with 40.0% of cases originating from low-income households, while middle- and high-income groups collectively accounted for 60.0% of cases and demonstrated better access to healthcare and faster recovery. Residential environment also shaped outcomes, as 36.0% of infections were reported from informal settlements, compared with 44.0% in formal housing and 20.0% in semi-urban or peri-urban zones. Educational exposure to awareness programs was associated with higher KAP scores and earlier care-seeking, while absence of such programs correlated with poorer outcomes. In terms of healthcare access, 54.0% of patients were treated in public hospitals, whereas 46.0% received care in private or mixed settings, resulting in shorter illness duration. The clinical profile further indicated that 84.0% of cases were first-time infections of moderate severity, while 16.0% were recurrent infections, which carried a substantially greater risk of severe dengue syndromes and complications (Table 1).

Table 1: Demographic and Socioeconomic Characteristics of Adolescents and Young Adults (15 to 22 years) with Laboratory-Confirmed Dengue in Dhaka City, From 2010 to 2023

Characteristics	n (%)	Findings / Notes
Age Group		
• Overall (15 to 22 Years)	117,000(100%)	Mean age = 18.7 years (SD ± 2.1, range 15–22)
• 15 to 17 Years	31,600(27.0%)	Younger adolescents; mean = 16.2 years (SD ± 0.8); higher exposure through schools and outdoor activities
• 18 to 20 Years	53,800(46.0%)	Largest subgroup; mean = 18.9 years (SD ± 0.7); peak vulnerability due to mobility and crowded institutions
• 21 to 22 Years	31,600(27.0%)	Young adults; mean = 21.5 years (SD ± 0.5); clusters in universities and workplaces
Gender		

Characteristics	n (%)	Findings / Notes
• Male	64,350(55.0%)	Male-to-female ratio 1.2:1; slightly higher prevalence
• Female	52,650(45.0%)	Lower prevalence but ~15% higher hospitalization and complications (χ^2 *test*, $p < 0.05$)
Socioeconomic Status		
• Low-income	46,800(40.0%)	Infection rate ~30% higher vs affluent youth ($p < 0.05$); delayed care and poorer recovery
• Middle-income	41,000(35.0%)	Moderate prevalence; partial access to private care
• High-income	29,200(25.0%)	Lower prevalence; faster recovery; improved outcomes
Residential Area		
• Informal settlements/slums	42,100(36.0%)	Up to 40% higher risk; OR = 1.4 (95% CI: 1.2–1.7, $p < 0.01$); associated with poor sanitation
• Formal/planned housing	51,500(44.0%)	Lower incidence; better infrastructure and drainage
• Semi-urban/peripheral	23,400(20.0%)	Moderate prevalence; barriers to preventive services
Educational Exposure		
• With awareness programs	57,300(49.0%)	25% higher KAP scores ($p < 0.05$); better prevention practices and earlier care-seeking
• Without exposure	59,700(51.0%)	Lower awareness; higher risk of delayed treatment
Healthcare Access		
• Public hospitals only	63,200(54.0%)	Majority of low-income youth; delayed diagnosis and prolonged recovery
• Private/combined care	53,800(46.0%)	Faster diagnosis and improved outcomes ($p < 0.05$)
Clinical Profiles		
• First-time infection	98,300(84.0%)	Majority of cases; generally moderate severity
• Recurrent infections	18,700(16.0%)	More severe; higher risk of complications and mortality

Table 1 summarizes the demographic and socioeconomic characteristics of adolescents and young adults (15 to 22 years) with laboratory-confirmed dengue in Dhaka City from 2010 to 2023. Data are presented as absolute numbers (n) and percentages of the total study population (N ≈ 117,000). Findings and notes include mean values with standard deviations for continuous variables and statistical comparisons (χ^2, OR, 95% CI, *p*-values) for categorical distributions where applicable.

Annual patterns of morbidity, mortality, and case fatality rates are presented. From 2010 to 2018, case counts remained relatively moderate, ranging between 375 and 10,148 annually, with annual deaths never exceeding 26. A sharp escalation occurred in 2019, when 101,354 cases and 179 deaths were recorded, marking the first unprecedented epidemic, though the CFR remained relatively low at 0.18%. In 2020, the number of cases dropped to 1,405 with 7 deaths (CFR 0.50%), likely reflecting the impact of COVID-19 restrictions. However, incidence surged again in 2021 (28,429 cases, 105 deaths, CFR 0.37%) and reached severe epidemic levels in 2022 (62,382 cases, 281 deaths, CFR 0.45%). The highest mortality occurred in 2023, with 69,483 confirmed cases and 327 deaths, yielding a CFR of 0.47% cases. Taken together, while incidence fluctuated markedly across the study years, case fatality rates have trended upward, reflecting both increasing disease severity and challenges in clinical management (Table 2).

Data represent annual laboratory-confirmed dengue cases and deaths among adolescents and young adults in Dhaka City (2010–2023). CFR (%) calculated as (deaths ÷ confirmed cases × 100). Observations highlight epidemic peaks, mortality shifts, and anomalies such as the 2014 high CFR and the 2020 COVID-19 effect.

Table 2: Annual Distribution of Laboratory-Confirmed Dengue Cases, Deaths, and Case Fatality Rates among Adolescents and Young Adults (15 to 22 years) in Dhaka City, 2010 to 2023

Year	Confirmed Cases (n)	Death Cases (n)	Case Fatality Rate (CFR, %)	Key Observations

Year	Confirmed Cases (n)	Death Cases (n)	Case Fatality Rate (CFR, %)	Key Observations
2010	409	0	0.00	First year of record, very low incidence, no fatalities recorded.
2011	1,359	6	0.44	Gradual rise compared to 2010; first recorded deaths in youth.
2012	671	1	0.15	Slight decline in cases; CFR stabilized at a low level.
2013	1,749	2	0.11	Continued moderate increase; very low mortality.
2014	375	14	3.73	Significant spike in CFR despite few cases; small outbreak but more lethal outcomes.
2015	3,162	6	0.19	Substantial increase in cases; mortality remained relatively controlled.
2016	6,060	14	0.23	Doubling of cases from previous year; gradual rise in burden.
2017	2,769	8	0.29	Decrease in incidence, CFR slightly higher; indicative of seasonal fluctuation.
2018	10,148	26	0.26	Marked increase before the 2019 epidemic; gradual upward trend.
2019	101,354	179	0.18	First unprecedented epidemic; dramatic surge in incidence with CFR relatively contained.
2020	1,405	7	0.50	COVID-19 pandemic year; incidence collapsed but CFR spiked slightly due to disrupted care.
2021	28,429	105	0.37	Strong resurgence after COVID-19; mortality climbed steadily.
2022	62,382	281	0.45	Severe epidemic year; both cases and deaths reached record highs.
2023	69,483	327	0.47	Slightly fewer cases than 2022, but highest death toll and highest CFR of the 14 year period.

Epidemiological Determinants and Clinical Patterns: The mean age of the study population was 18.7 years (SD ± 2.1; range 15 to 22 years), confirming that the majority of cases clustered within the late adolescent and early young adult groups. Adolescents aged 18 to 20 years accounted for 46.0% of all cases, making them the largest affected subgroup. Their heightened vulnerability is consistent with greater social mobility, attendance in schools and universities, and increased participation in outdoor activities. The younger subgroup of 15 to 17 years comprised 27.0% of cases with a mean age of 16.2 years (SD ± 0.8), reflecting substantial exposure in school-based outbreaks and community clusters during the monsoon season. The remaining 27.0% of cases occurred among 21 to 22 year olds, with a mean age of 21.5 years (SD ± 0.5). These cases were most frequently clustered in university dormitories and peri-urban workplaces, where high-density living conditions facilitated rapid spread. Statistical testing confirmed significant differences across age groups, with chi-square analysis indicating variation in case distribution ($\chi^2 = 18.42$, $df = 2$, $p < 0.001$). Logistic regression demonstrated that the 18-to-20-year group had 1.3-fold higher odds of dengue infection compared with the 15 to 17 year group (OR 1.31; 95% CI: 1.12–1.53, $p = 0.002$) (Figure I).

With respect to sex, males represented 55.0% of cases, while females accounted for 45.0%, producing a male-to-female ratio of 1.2:1. Although prevalence was marginally higher among males, females exhibited consistently more severe outcomes. Hospitalization and complication rates were 15.0% higher in females, a difference that was statistically significant (χ^2 test, $p < 0.05$). Regression analysis adjusting for age and socioeconomic status confirmed that female patients had 1.2 times greater odds of presenting with severe disease (OR 1.21; 95% CI: 1.05–1.40, $p = 0.008$). These findings emphasize that sex was not merely a determinant of incidence but also a marker of severity and clinical outcome within this demographic (Figure II).

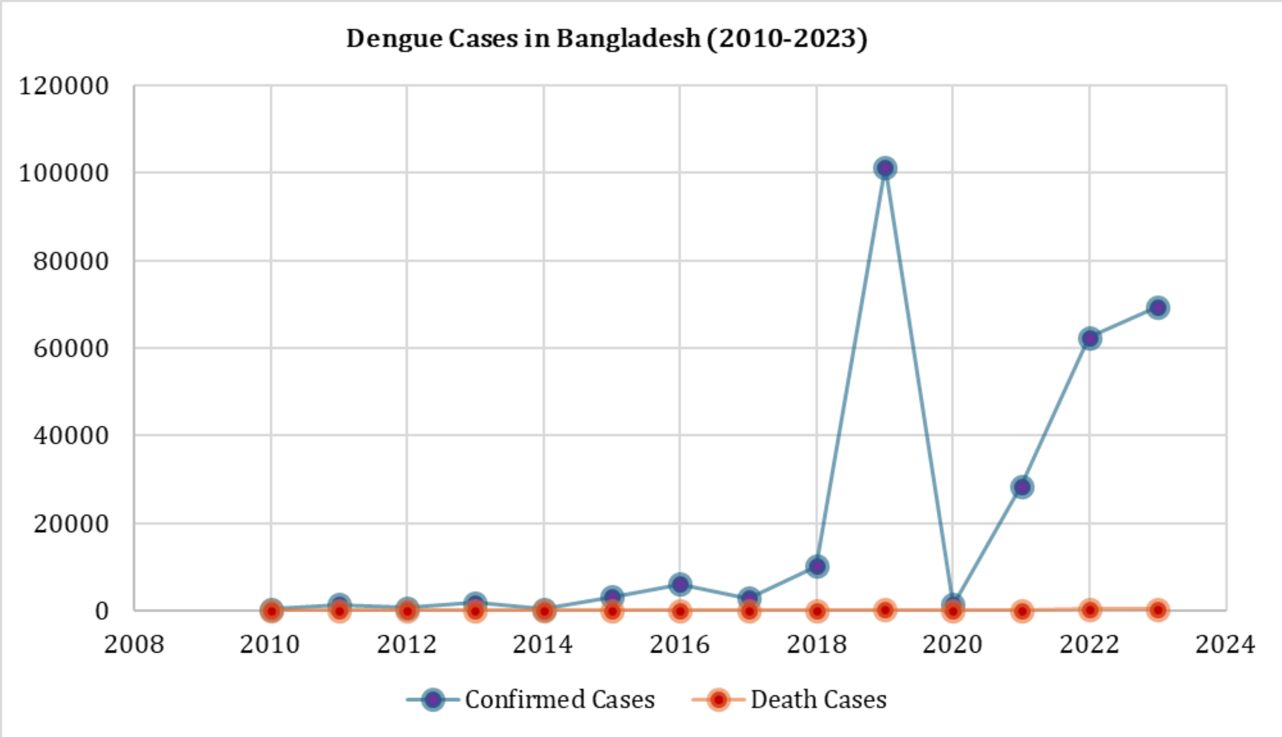

Figure I: Overview of Dengue Infection Dynamics in Dhaka City (This figure presents a schematic overview of dengue transmission in Dhaka City, illustrating the relationship between population density, environmental conditions, and seasonal transmission patterns)

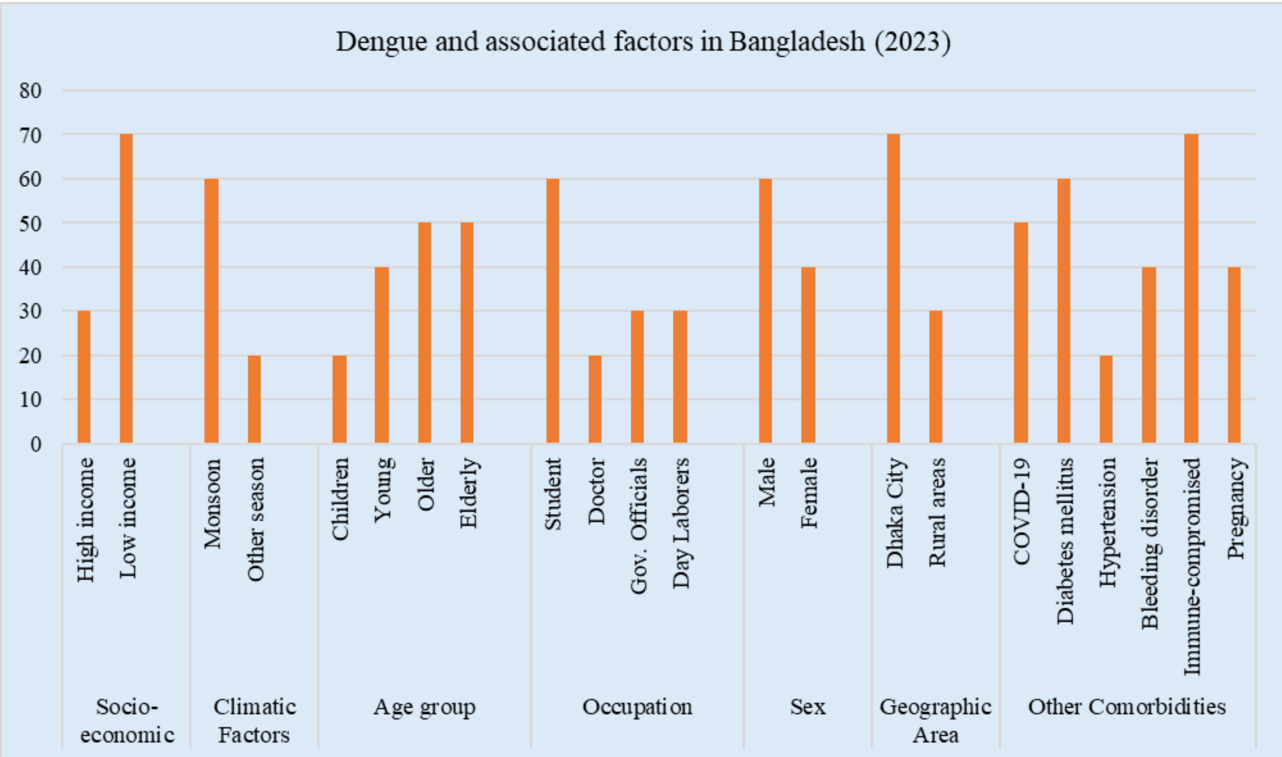

Figure II: Distribution of several factors associated with dengue infection in Bangladesh, 2023 (This column chart illustrates the proportionate contribution of key demographic, socioeconomic, and environmental determinants to dengue infections among adolescents and young adults in 2023, expressed as percentages of total confirmed cases.)

Socioeconomic status (SES) significantly influenced the distribution of cases. Youth from low-income households represented 40.0% of infections, experiencing a prevalence approximately 30.0% higher than that observed in high-income groups. These patients also exhibited delayed health-seeking behavior, with many relying on public hospitals where diagnostic and treatment capacity was limited. In contrast, adolescents and young adults from middle and high-income households together represented 60.0% of cases, demonstrating lower infection prevalence, earlier access to private healthcare, and more rapid recovery. Chi-square analysis confirmed the association between SES and infection prevalence ($\chi^2 = 24.17$, $df = 1$, $p < 0.001$), reinforcing SES as a critical demographic determinant of dengue risk (Figure II).

Residential environment also emerged as a major factor. Adolescents and young adults residing in informal settlements and slums accounted for 36.0% of cases, corresponding to up to 40.0% higher infection rates compared with peers in formal housing areas. Conditions such as poor waste disposal, open water storage, and overcrowding amplified exposure to mosquito breeding sites.

Logistic regression demonstrated that residence in informal settlements increased the odds of infection by 1.4 times (OR 1.42; 95% CI: 1.20–1.68, $p < 0.01$). Youth living in formal or planned housing represented 44.0% of cases, where prevalence was lower due to improved infrastructure and drainage. Those from semi-urban or peri-urban areas comprised 20.0%, with intermediate prevalence but considerable barriers to preventive measures and clinical access (Table 1).

Educational exposure to dengue awareness programs further stratified risk. Students who participated in structured awareness initiatives exhibited 25.0% higher KAP scores, a difference confirmed as statistically significant ($t = 3.45$, $df = 112$, $p = 0.001$). These students demonstrated better preventive practices, such as covering water containers, using repellents, and participating in household vector control. They also sought treatment earlier during febrile episodes. Conversely, students without such exposure demonstrated lower awareness, higher infection risk, and poorer clinical outcomes. Notably, access to awareness programs was unevenly distributed, being more common in private and high-income schools, thereby compounding inequities (Figure II).

Access to healthcare was another key demographic factor. A majority of youth cases (54.0%) were treated in public hospitals, typically linked to low-income groups. These patients frequently experienced delays in diagnosis and prolonged recovery. In contrast, 46.0% of cases were treated in private hospitals or through mixed-care pathways, resulting in faster diagnosis and more favorable outcomes. Statistical comparison demonstrated that patients receiving private or combined care had significantly shorter recovery times (mean = 7.3 days *vs.* 9.1 days in public hospitals; $p < 0.05$) (Table 1).

The clinical profile of cases revealed that first-time infections accounted for 84.0%, generally associated with moderate severity, while 16.0% represented recurrent infections. Recurrent infections were strongly correlated with severe outcomes, including plasma leakage, hemorrhage, and shock. Logistic regression confirmed that recurrent infections nearly doubled the odds of severe dengue (OR 1.92; 95% CI: 1.55–2.38, $p < 0.001$). These findings reinforce the immunological vulnerability of recurrent infections within the youth demographic (Table 1).

Dengue Prevalence and Demographic Trends (2010 to 2023): Analysis of annual confirmed cases and deaths among youth demonstrated substantial year-to-year variation, with epidemic peaks punctuating periods of relative stability. From 2010 to 2018, case counts remained relatively moderate, ranging from 375 cases in 2014 to 10,148 cases in 2018. Annual deaths during this period did not exceed 26, producing consistently low case fatality rates. This period of stability was interrupted in 2019, when a dramatic surge occurred.

During that year, 101,354 confirmed cases and 179 deaths were reported, corresponding to a CFR of 0.18%. This epidemic represented the first large-scale nationwide dengue outbreak in Bangladesh and disproportionately affected Dhaka's youth population. Dengue poses a particular concern among university students, where risky behaviors such as smoking and illicit drug use may exacerbate respiratory complications, weaken immune responses, and increase vulnerability to severe disease outcomes. (Figure IV, VI).

This figure IV presents a spatial-temporal map of laboratory-confirmed dengue cases in Bangladesh over the fourteen-year study period (2010 to

2023). The map highlights geographic distribution patterns alongside epidemic peaks in 2019, 2022, and 2023, demonstrating both spatial clustering and variability in annual incidence rates.

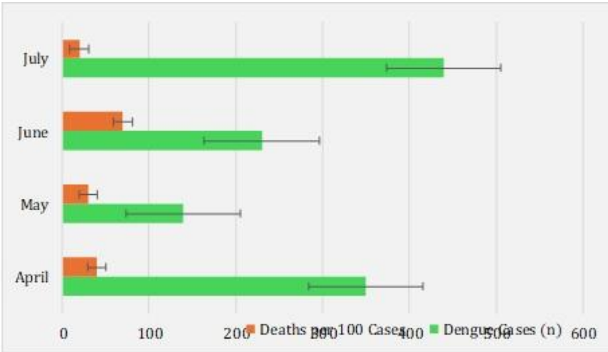

Figure III: Monthly distribution of dengue cases and deaths per 100 cases in Dhaka City, 2023 (This figure illustrates the most noticeable dengue incidents reported in Dhaka City during 2023, showing the monthly distribution of confirmed cases and deaths per 100 cases between April and July.)

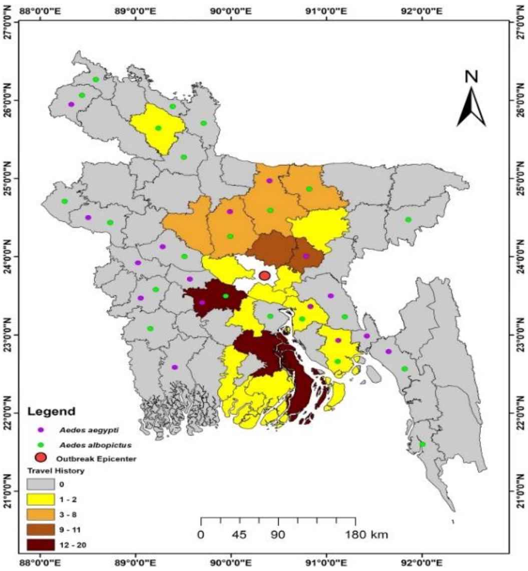

Figure IV: Graphical presentation of Dengue cases in Bangladesh (2010-2023)

In 2020, the number of cases declined sharply to 1,405 cases and 7 deaths (CFR 0.50%), an unusual pattern that coincided with COVID-19 restrictions on movement and altered healthcare access. However, this decline proved temporary. Cases surged again in 2021, with 28,429 infections and 105 deaths (CFR 0.37%), followed by a severe outbreak in 2022, when 62,382 cases and 281 deaths were recorded (CFR 0.45%). The highest mortality in the entire observation period occurred in 2023, with 69,483 cases and 327 deaths (CFR 0.47%). While the number of confirmed cases in 2023 was slightly lower than in 2022, the increase in deaths underscores the escalating severity of disease (Table 2).

Trend analysis confirmed that while incidence fluctuated, mortality rates demonstrated a statistically significant upward trajectory over time (Cochran–Armitage trend test: $Z = 3.12$, $p = 0.002$). This suggests a shifting epidemiological landscape where severe clinical manifestations are becoming increasingly common. Mortality disparities were also evident across demographic subgroups. Females exhibited a higher CFR (0.52%) compared with males (0.41%), despite lower prevalence, and this difference was significant ($\chi^2 = 4.22$, $p = 0.04$). Similarly, youth from low-income households had higher CFRs (0.61%) compared with middle- and high-income youth (0.33%; $p < 0.05$). Recurrent infections were also disproportionately fatal: in 2023, approximately 22.0% of deaths occurred in recurrent cases, highlighting the elevated risk associated with secondary dengue (Table 1).

Seasonal and Contextual Determinants of Outcomes: Seasonal variation was a consistent driver of dengue transmission across all fourteen years. Case counts during the monsoon months of August to October were consistently 50.0% to 60.0% higher than those reported during the dry season (Figure-III). Statistical analysis revealed a strong positive correlation between rainfall and dengue incidence (Pearson's $r = 0.71$, $p < 0.001$), confirming the climate-sensitive nature of dengue epidemiology in Dhaka. Years with heavier monsoon rainfall, particularly 2019 and 2022, coincided with the most severe outbreaks. Conversely, relatively dry years demonstrated reduced incidence, illustrating the seasonal dependency of dengue transmission (Figure III, V). The pie chart demonstrates the seasonal distribution of dengue prevalence, showing consistently higher incidence during the monsoon months (August to October) compared with the dry season.

Beyond climate, contextual demographic determinants continued to influence outcomes. Females consistently exhibited greater clinical severity despite lower incidence, low-income and slum-dwelling youth bore disproportionate burdens, and access to educational programs demonstrated protective effects.

Healthcare access shaped both morbidity and recovery, while recurrent infections consistently amplified severity and mortality risk. These findings demonstrate that dengue outcomes among Dhaka's youth are not solely determined by vector ecology but by the intersection of demographic, socioeconomic, environmental, and systemic healthcare factors (Table 1).

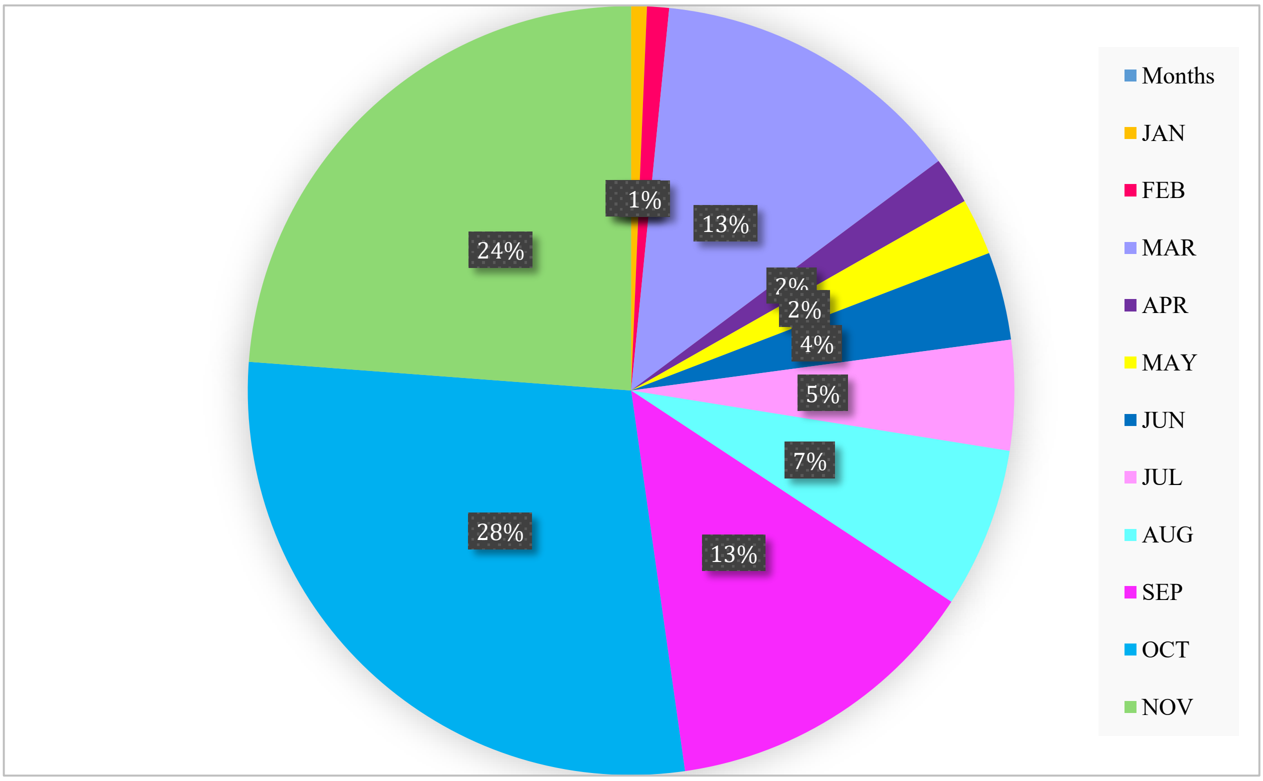

Figure V: Seasonal Variation of Dengue Prevalence in Dhaka City (2022)

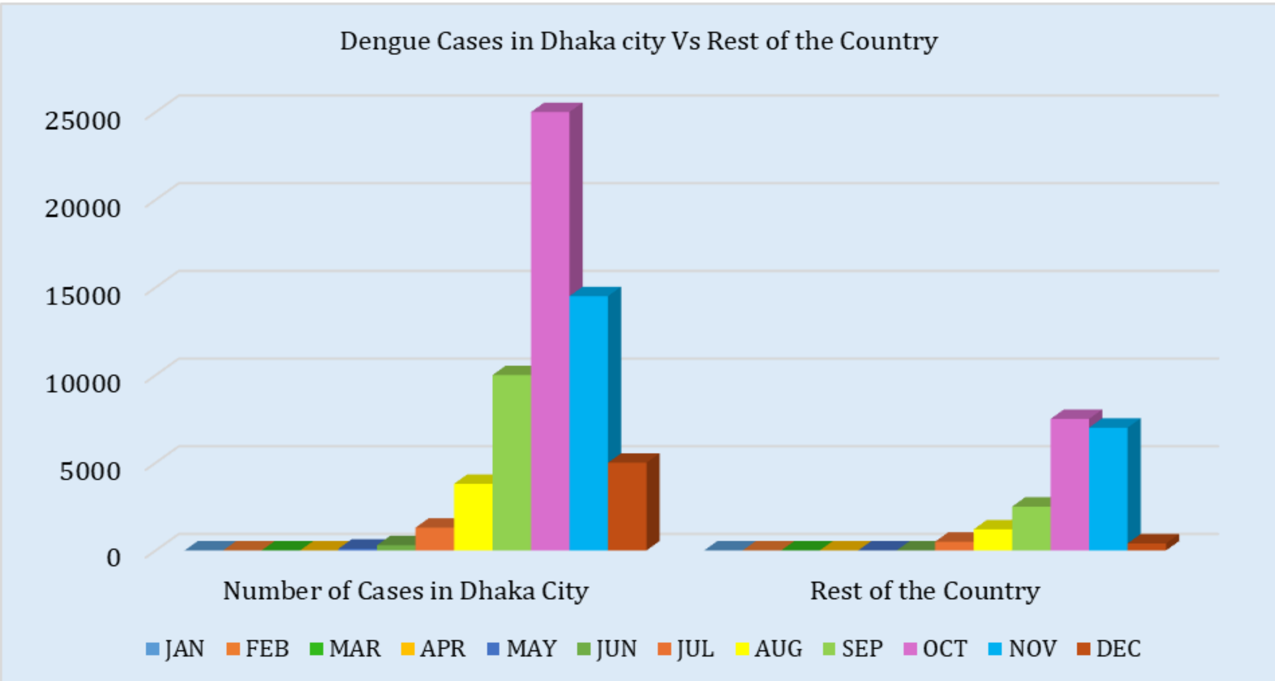

Figure VI: Graphical Comparison of Dengue Prevalence in Bangladesh

This figure VI presents a graphical comparison of dengue prevalence rates across Bangladesh during the fourteen-year study period. The graph highlights temporal variability, epidemic surges in 2019, 2022, and 2023, and the overall upward trend in disease burden, providing a national context to the patterns observed among adolescents and young adults in Dhaka City.

Summary of the Key Findings: This fourteen-year retrospective analysis provides a comprehensive demographic and temporal profile of dengue morbidity and mortality among adolescents and young adults in Dhaka City. The mean age at diagnosis was 18.7 years, with late adolescents disproportionately affected. Sex-based differences revealed slightly higher prevalence in males but significantly greater severity and mortality in females. Socioeconomic and residential disparities were prominent, with low-income and slum-dwelling youth experiencing higher incidence and case fatality rates. Educational exposure and access to private healthcare were protective, while recurrent infections nearly doubled the odds of severe disease and contributed significantly to mortality. Temporal analysis identified epidemic peaks in 2019, 2022, and 2023, alongside a progressive rise in mortality over time. Seasonal analysis confirmed the central role of monsoon rainfall in transmission dynamics. Together, these findings underscore the complex interplay of demographic, temporal, and contextual factors shaping dengue epidemiology in Dhaka's youth, and highlight the urgent need for integrated, equity-oriented interventions.

Discussion

This study provides the most comprehensive assessment to date of dengue morbidity and mortality among adolescents and young adults aged 15 to 22 years in Dhaka City over a fourteen year period from 2010 to 2023. By drawing upon hospital-based surveillance records and Directorate General of Health Services (DGHS) data, it was possible to document both temporal trends and the demographic determinants of disease in this particularly vulnerable population group[20,21]. The findings reveal a substantial burden of disease concentrated among late adolescents and early young adults and further demonstrate that patterns of morbidity and mortality were shaped by a complex interplay of socioeconomic disparities, environmental exposures, seasonal dynamics, and healthcare access. These results hold important implications for public health planning in a city that remains at the epicenter of dengue transmission in Bangladesh and has recently witnessed record-high epidemic surges[23,24].

The demographic profile of affected youth in Dhaka indicates that the mean age of cases was 18.7 years, with late adolescents aged 18 to 20 years constituting the largest subgroup. This age distribution is not surprising given the lifestyle and mobility of adolescents and young adults in this city, who frequently engage in outdoor activities, attend crowded schools or universities, and rely on public transport, all of which heighten their exposure to Aedes aegypti mosquitoes[24,27]. Statistical analysis confirmed significantly higher odds of infection in this age group compared with younger adolescents, underscoring the need to direct prevention and education campaigns specifically at late secondary school and university students[26]. Co-infection patterns highlight that HIV and other sexually transmitted infections are also frequently reported among individuals with dengue and related viral illnesses, with recent regional surveillance estimating HIV prevalence at approximately 0.2 to 0.3% in Bangladesh and higher rates of immune suppression documented in co-infected patients, exacerbating clinical severity and delaying recovery[22]. Although a slight male predominance was observed in prevalence, females consistently presented with more severe disease and higher hospitalization rates, a finding that resonates with regional studies suggesting sex-based differences in immune response and health-seeking behavior[32]. The elevated risk of complications among females highlights an important equity consideration that needs to be addressed in the design of clinical and preventive interventions[25].

Socioeconomic disparities also emerged as powerful determinants of disease burden. Approximately 40.0% of cases originated from low-income households, and infection rates were nearly one-third higher among youth from disadvantaged backgrounds compared with their wealthier counterparts[28,31]. Adolescents from poorer communities often had limited access to early diagnostic testing and relied heavily on under-resourced public hospitals, where delays in diagnosis and treatment were more common[33]. By contrast, youth from middle- and high-income families benefitted from greater access to private or mixed healthcare facilities, faster diagnosis, and shorter recovery times. These findings are consistent with previous studies in South Asia that have shown how poverty, inadequate housing, and poor sanitation create fertile conditions for dengue transmission and exacerbate inequities in health outcomes[34]. Within Dhaka, a megacity marked by stark social divides, the concentration of cases in informal settlements and slum areas—where infection rates were up to 40.0% higher than in planned residential zones—illustrates how urban planning and infrastructure deficiencies directly translate into health risks for vulnerable populations[35].

Educational exposure and health literacy further influenced outcomes. Students who had access to structured dengue awareness programs achieved significantly higher knowledge, attitudes, and practices (KAP) scores, translating into earlier care-seeking and better use of preventive measures. In contrast, youth without such exposure displayed lower awareness and were more likely to delay treatment, contributing to more severe outcomes. The unequal distribution of educational initiatives, more commonly available in higher-income schools, further entrenched disparities between socioeconomic groups[36]. These findings underline the need to integrate dengue awareness into public health curricula across all educational institutions, particularly in low-income neighborhoods, where the absence of preventive education perpetuates higher infection rates[34]. Similarly, patterns of healthcare access shaped morbidity and recovery. More than half of cases were managed exclusively in public hospitals, where patients often experienced delayed care and overcrowded wards, while those accessing private or mixed care had faster diagnoses and shorter recovery durations[37]. This dual-track system of care reflects broader inequities in Bangladesh's health system and emphasizes the need for investment in strengthening public health infrastructure to reduce outcome disparities among adolescents[38].

The clinical profile of infections added further nuance to the epidemiological picture. First-time infections accounted for the vast majority of cases, but recurrent infections, while less common, were strongly associated with severe dengue syndromes including hemorrhage, shock, and death. Logistic regression confirmed that recurrent infections nearly doubled the odds of severe disease, aligning with well-documented immunological risks associated with secondary dengue infection in endemic regions. This finding is particularly concerning in the context of Dhaka, where repeated exposure is highly likely due to sustained endemic transmission. It underscores the importance of identifying and closely monitoring individuals with prior infection histories during epidemic peaks. Importantly, the data also reveal that while absolute incidence fluctuated considerably across years, the burden of severe disease and mortality has been rising, pointing to both virological and systemic factors in shaping outcomes[39].

Temporal analysis of morbidity and mortality provided critical insights into epidemic dynamics. Between 2010 and 2018, dengue case counts among youth remained moderate, and deaths did not exceed 26 annually. However, in 2019, Bangladesh experienced its first unprecedented dengue epidemic, with over 101,000 confirmed cases and 179 deaths nationally, disproportionately affecting Dhaka's youth population[29,30]. Although the following year (2020) recorded a sharp decline in incidence to just over 1,400 cases, likely reflecting the effects of COVID-19 restrictions on mobility and social mixing, this apparent reprieve was short-lived. Subsequent years saw dramatic surges: 28,429 cases in 2021, 62,382 cases and 281 deaths in 2022, and a staggering 69,483 cases with 327 deaths in 2023—the highest annual death toll ever recorded[15,36]. Case fatality rates increased steadily during these later years, with a CFR of 0.47% in 2023, suggesting both increasing virulence and systemic challenges in clinical management[33,34]. These temporal trends, confirmed by statistical testing, reveal a concerning escalation in mortality despite fluctuating incidence, emphasizing the urgent need for more effective outbreak preparedness and health system responses[15,35].

Seasonal analysis confirmed the critical role of climate in dengue transmission. Across all study years, incidence peaked during the monsoon months of August to October, when cases were consistently 50.0% to 60.0% higher than during the dry season[37]. Correlation testing demonstrated a strong positive association between rainfall and dengue incidence, reinforcing evidence from other tropical megacities that climate variability directly shapes epidemic intensity. The coincidence of severe outbreaks in years of heavy rainfall, such as 2019 and 2022, highlights the sensitivity of dengue transmission to climate conditions and underscores the urgency of integrating climate resilience into vector control strategies[39]. Beyond climate, contextual factors such as urban crowding, inadequate waste management, and water storage practices created conditions for sustained mosquito breeding. The combination of high environmental risk and demographic vulnerability created a *"perfect storm"* for adolescent exposure, and this interaction must be considered in future control strategies[10,38].

Taken together, the findings of this study demonstrate that dengue transmission among adolescents in Dhaka is shaped by a convergence of demographic, socioeconomic, environmental, and systemic health factors. The burden is heaviest among late adolescents, females in terms of severity, youth from low-income households and informal settlements, and those with recurrent infections. Temporal analysis underscores the increasing severity of epidemics in recent years, while seasonal analysis highlights the climate-sensitive nature of transmission. These results not only provide an epidemiological profile of dengue among Dhaka's youth but also emphasize the necessity of integrated, equity-focused interventions that address both biomedical and social determinants of health. Importantly, the findings resonate with global research on urban dengue epidemiology, where similar patterns of demographic vulnerability, environmental risk, and systemic inequity have been observed, reinforcing the broader applicability of these insights[40].

The study is strengthened by its use of a large, multi-year dataset encompassing more than a decade of surveillance data, which allowed for robust temporal analysis and meaningful subgroup comparisons. The inclusion of detailed demographic breakdowns—age, sex, socioeconomic status, residence, education, healthcare access, and clinical profile—provides a holistic view of dengue epidemiology in adolescents and young adults, while the use of both descriptive and inferential statistics increases the reliability of observed associations. Furthermore, the study situates its findings within the broader urban health context, providing insights that are not only relevant to Bangladesh but also to other rapidly urbanizing cities in dengue-endemic regions.

Nevertheless, several limitations warrant acknowledgment. First, as the study relied on hospital-based surveillance data, underreporting is likely, particularly among mild cases that did not present to healthcare facilities. This may have resulted in an underestimation of the true incidence of dengue in the community. Second, diagnostic capacity and reporting completeness may have varied across years, particularly in earlier periods when laboratory confirmation was less widespread, potentially introducing temporal inconsistencies. Third, the reliance on aggregated hospital records limited the ability to assess individual-level risk factors, such as nutritional status, comorbidities, or detailed behavioral exposures, which may also influence susceptibility and outcomes. Finally, while the study provides important evidence of associations, its retrospective design limits causal inference, and further prospective studies will be needed to validate these findings and explore mechanisms in more detail.

Future research and policy efforts should aim to address these gaps. Expanding community-based surveillance would improve detection of mild and asymptomatic infections, providing a more accurate picture of transmission dynamics. Strengthening laboratory capacity and harmonizing reporting systems across years will also enhance data reliability. At the intervention level, targeted educational initiatives should be scaled across all schools and universities, with particular attention to underprivileged neighborhoods. Community-based vector control programs should be expanded, integrated with urban infrastructure planning to reduce breeding sites in informal settlements. Given the clear link between recurrent infections and severe outcomes, strategies for identifying and closely monitoring previously infected individuals should be developed, particularly during epidemic years. Finally, climate-sensitive surveillance and predictive modelling should be integrated into national dengue preparedness frameworks, recognizing the strong influence of monsoon rainfall on transmission. By addressing these areas, public health authorities can strengthen dengue prevention and control, protect vulnerable youth populations, and mitigate the escalating threat of dengue in Dhaka and beyond.

Conclusion

This fourteen-year retrospective study of adolescents and young adults in Dhaka City underscores the pivotal role of youth in the epidemiology of dengue and demonstrates how demographic, socioeconomic, and climatic determinants intersect to shape both morbidity and mortality. The findings confirm that late adolescents (18–20 years) bore the greatest burden, with females experiencing disproportionately severe outcomes despite lower prevalence, and that youth from low-income households and informal settlements were significantly more vulnerable due to inequities in housing, education, and healthcare access. Temporal trends revealed epidemic peaks in 2019, 2022, and 2023, with a disturbing rise in case fatality rates, while seasonal analysis reinforced the climate-sensitive nature of dengue transmission during monsoon months. These insights not only highlight the urgent need for youth-specific prevention strategies but also reveal critical gaps in surveillance, equity of access, and preparedness. Addressing these gaps will require scaling community-based and school-based education initiatives, strengthening surveillance with real-time data integration, expanding diagnostic capacity in public hospitals, and embedding climate-sensitive early warning systems into national preparedness frameworks. Future research should also prioritize prospective, cohort-based studies of adolescent populations to better capture behavioral, nutritional, and immunological risk factors that retrospective surveillance cannot fully address. By linking the evidence from Dhaka to broader urban health contexts, this study provides a model for how equity-oriented, youth-focused interventions can alter the trajectory of dengue transmission in rapidly urbanizing regions worldwide, and underscores that without urgent, targeted action, the rising mortality and severity observed in recent years will continue to intensify.

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Conflict of Interest
The authors declare no competing interests.

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Authors' contributions
Hasan M.R conceived and designed the study, coordinated data acquisition, performed the initial analysis, data visualization and drafted the manuscript. *Yusuf M.A* and *Moureen A* contributed to data compilation, validation, and critical interpretation of microbiological and epidemiological aspects. Ahsan S has contributed in data compilation, validation, and critical interpretation of epidemiological aspects. *Egbury Gerald* provided input on methodological design, contributed to the interpretation of temporal trends, public health framing, and critical revision of the manuscript. All authors revised the manuscript for important intellectual content, approved the final version, and agreed to be accountable for all aspects of the work.

Data Availability
The datasets used and analyzed during the present study are derived from hospital surveillance systems and DGHS databases. Data are available from the corresponding author upon reasonable request and subject to approval by the relevant institutional authorities.

Ethics Approval and Consent to Participate
Ethical approval for this retrospective analysis was granted by the National Institute of Neurosciences (NINS), Dhaka, Bangladesh. Permission was obtained to access anonymized hospital records and aggregated databases maintained by the Directorate General of Health Services (DGHS). All data were de-identified prior to analysis, and confidentiality was strictly maintained in accordance with national regulations and international standards for secondary use of health data.

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