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Research Article

Testing, Mortality, and Vaccination Disparities: A Post-Analysis of COVID-19 Trends in Bangladesh

*[1]Md Raiyan Hashar, [2]Nushrat Maliha, [3]Shahnoor Shabab, [4]Maisha Maliha Misha, [5]Hafsa Akter, [6]Chandrima Halder, [7]Sheikh Sadeka Binte Rob

About Article

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About Author

[1] Department of Public Health, World University of Bangladesh, Bangladesh

[2] Chattogram Maa O Shishu Hospital Medical College, Bangladesh

[3] Jashore Medical College and Hospital, Bangladesh

[4] Internal Medicine, Jashore Medical College and Hospital, Bangladesh

[5] Faridpur medical College and Hospital, Bangladesh

[6] Army Medical College Chattogram, Bangladesh

[7] Department of Physics, National University, Bangladesh

Contact @ Md Raiyan Hashar
raiyan.hsr@gmail.com

ABSTRACT

The COVID-19 pandemic exposed structural weaknesses in Bangladesh's health system that were shaped by uneven access to testing and vaccination. We analyzed data from the World Health Organization and the Directorate General of Health Services from 2020 to 2023. Bangladesh reported a little over two million confirmed cases and nearly thirty thousand deaths. The case fatality rate was about 1.44 %. Testing reached about 9.3 % of the population and the positivity rate was about 13 %, which suggests substantial under-detection outside major cities. Vaccination coverage passed four fifths for at least one dose, but it varied across districts. Dhaka reached about 97 % for first-dose coverage while Mymensingh was near 70 %. Gazipur reported coverage above 100 %, which likely reflects doses given to migrants or people who do not reside there. Booster uptake was inconsistent and ranged from very low in some districts to 62 % in Chuadanga. The main conclusion is that pandemic outcomes were driven more by district-level inequities in detection and protection than by national averages. The primary implication is that Bangladesh and similar countries should invest in district-focused programs that expand local testing capacity, strengthen routine mortality surveillance, and deliver data-guided vaccine and booster services to underserved areas. These steps would close observed gaps and improve readiness for the next health emergency.

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1. INTRODUCTION

The COVID-19 pandemic which is caused by the SARS-CoV-2 virus, became a global health emergency and placed tremendous strain on healthcare systems globally. In Bangladesh, the crisis exposed deep-seated limitations in testing capacity, mortality management, and vaccine distribution. As a low and middle-income country (LMIC), Bangladesh grappled with medical & structural challenges such as insufficient diagnostic facilities, economic pressures, and striking differences in healthcare access between regions. These constraints contributed shaping the detected cases, managed fatalities, and rolled out immunization, with each aspect influencing the others in ways that affected public health resilience.

On the global stage, the pandemic laid striking disparities in outcomes, tied to variations in infrastructure, testing policies, and government responses (Hale *et al.*, 2021). LMICs, in particular, struggled with limited access to diagnostic tools, which hampered disease surveillance andcontributed to underreported case numbers and higher fatality rates (Kavanagh *et al.*, 2020). In Bangladesh, the reliance on rapid antigen tests along with relatively scarce polymerase chain reaction (PCR) facilities in rural areas may have left many infections undetected (Anwar *et al.*, 2020). Exploring these limitations offers valuable insight into the country's ability to track and control transmission, sheds light on challenges which the LMIC countries face.

Patterns of mortality during COVID-19 depended on several factors, including healthcare access, age demographics, and the timing of interventions (Dowd *et al.*, 2020). For many LMICs, shortages of oxygen, intensive care beds, and trained staff worsened outcomes (Walker *et al.*, 2020). As Bangladesh has more young people, it had a lower death rate, but pressure on the health system during peak infection waves still presented major challenges (Shammi *et al.*, 2020). So, if we study the mortality trends, it will help us to understand both the direct burden of the disease and the capacity of the health system to withstand such shocks.

Vaccination efforts became a cornerstone of the pandemic response, but equal access to emergency resources remained elusive throughout the globe, especially for LMICs (Wouters *et al.*, 2021). Bangladesh rolled out a large-scale vaccination drive using several vaccine types, but uptake was uneven. Logistics, urban–rural divides, and occasional vaccine hesitancy all played a role in shaping coverage patterns (Paul *et al.*, 2021). Cities and towns with stronger health infrastructure often reached higher vaccination rates, while rural districts lagged — a disparity consistent with broader healthcare inequities (Jannat *et al.*, 2024). Understanding these differences is essential for evaluating the country's vaccination strategy and its public health impact.

In this study, we analyze national data from the World Health Organization (WHO) and Bangladesh's Directorate General of Health Services, focusing on trends in testing, mortality, and vaccination. Using descriptive statistics, we aim to identify how these three elements interacted during the pandemic and what they reveal about the resilience — and vulnerabilities — of Bangladesh's health system. The findings are intended to inform future policymaking for pandemic preparedness, with an emphasis on equity and the realities of resource-limited settings.

1.1. Research Questions (RQs)

RQ1: How does Bangladesh's COVID-19 death rate compare, and what factors explain the differences?

RQ2: What are the regional disparities in COVID-19 vaccination coverage across Bangladesh?

RQ3: How did testing and case detection trends change in Bangladesh after April 2022?

1.2. Research Objectives (ROs)

RO1: To analyze COVID-19 death rates in Bangladesh relative to global averages and potential under-detection.

RO2: To assess regional differences in second-dose COVID-19 vaccination coverage in Bangladesh.

RO3: To examine changes in COVID-19 testing and case reporting trends post-April 2022.

This study draws on data from WHO's global COVID-19 database, national health statistics, and vaccination updates from Bangladesh's Directorate General of Health Services. By focusing on testing, mortality, and vaccination disparities, it seeks to provide a comprehensive analysis of Bangladesh's COVID-19 response, offering lessons for public health planning in resource-limited settings.

2. LITERATURE REVIEW

The COVID-19 pandemic presented unprecedented challenges to public health systems worldwide, but the strain was especially acute in low- and middle-income countries (LMICs) such as Bangladesh. Resource constraints, both financial and infrastructural, meant that the country had to contend with the crisis under far less favorable conditions than many wealthier nations. This section synthesizes findings from peer-reviewed research on testing, mortality, and vaccination patterns in Bangladesh, with the aim of situating the present study in the broader body of pandemic-related literature.

2.1. Testing and case detection

Accurate testing is the cornerstone of pandemic control. Unfortunately, LMICs often lacked the diagnostic capacity to meet demand. In Bangladesh, cost pressures meant that rapid antigen tests were used most. While quick and relatively inexpensive, these tests are less sensitive than polymerase chain reaction (PCR) methods, and these likely resulted false negative results, especially in rural communities where PCR testing was rare (Anwar *et al.*, 2020). Testing facilities were also heavily concentrated in urban centers, causing many rural residents to travel long distances or go without testing at all. This uneven access may have distorted official case numbers and delayed public health responses, illustrating the difficulty of expanding diagnostic networks in limited resource areas.

2.2. Mortality trends

Death rates during the pandemic were caused by a complex mix of healthcare capacity, demographic structure, and the peak infection timing. In many LMICs, the lack of oxygen supplies, intensive care beds, and trained staff contributed to higher case fatality rates (Walker *et al.*, 2020). Bangladesh was no exception. During peak waves, overcrowded hospitals failed to meet patient needs, even though the country's younger population

helped keep mortality from climbing even higher (Shammi *et al.*, 2020). Evidence also suggests that many COVID-19 deaths, particularly in rural areas went unrecorded. (Shammi *et al.*, 2020). These discussed reasons underscore the importance of developing mortality surveillance systems that function reliably across both urban and rural areas.

2.3. Vaccination coverage and disparities

Vaccination was one of the most effective tools for reducing COVID-19's health and economic impact. Bangladesh's rollout, which involved several vaccine types, was ambitious but far from even. The logistics of maintaining cold chains and distributing doses to remote communities created clear regional disparities (Paul *et al.*, 2021). Cities, with better infrastructure and stronger health communication networks, saw higher uptake than rural areas (Jannat *et al.*, 2024). In some places, misinformation and vaccine hesitancy further complicated efforts to reach target coverage levels (Paul *et al.*, 2021). These disparities reflect a wider issue in LMIC health systems: structural and social barriers that persist even when medical supplies are available.

2.4. Gaps in the literature

Although existing studies offer valuable perspectives, important blind spots remain. Little has been published on testing trends in Bangladesh after 2022, when global restrictions were lifted and testing demand shifted. There is also limited understanding of how regional disparities in vaccination rates might shape longer-term patterns of transmission and immunity. Finally, the true extent of mortality underreporting — and how it might affect health policy and preparedness — has yet to be fully quantified. The present study seeks to address some of these gaps by drawing on reliable datasets to examine testing, mortality, and vaccination trends in a unified analysis.

3. METHODOLOGY

This study uses a descriptive research design to examine how COVID-19 unfolded in Bangladesh, with a focus on both epidemiological patterns and vaccination coverage. The analysis is intended to do three things: measure key pandemic indicators, compare national outcomes with global averages, and highlight differences in vaccination rates across the country's administrative divisions. All data come from established, credible sources — specifically official national and international databases — ensuring consistency and reliability. No primary data were collected; instead, the work builds on existing datasets to provide a clear picture of trends over time and across regions.

3.1. Data sources

All data used in this study were obtained from publicly accessible dashboards and reports:

- WHO COVID-19 Global Data Dashboard
- World Health Statistics Reports
- Bangladesh Directorate General of Health Services (DGHS) COVID-19 Dashboard
- Bangladesh DGHS COVID-19 Vaccination Update Dashboard

3.1.1. The dataset included

- Total population
- Number of COVID-19 laboratory tests conducted
- Total confirmed COVID-19 cases
- Total reported COVID-19 deaths
- Regional COVID-19 vaccination coverage for the second dose, expressed as a percentage of the total population

3.2. Analytical approach

We applied descriptive statistical methods to calculate the main epidemiological indicators and to summarize vaccination coverage. In simple terms, this meant organizing and presenting the data in a way that made patterns easier to see — for example, by calculating frequencies, percentages, and ratios, and by producing tables and graphs to illustrate trends. This type of analysis is appropriate when the goal is to describe what the data show, rather than to carry out hypothesis testing or make inferences about populations beyond the dataset itself.
Definitions of Key Indicators
The following epidemiological indicators were calculated:
Test-to-Population Ratio (Test/Pop) This ratio measures the percentage of the population that underwent COVID-19 testing:

- Test-to-Population Ratio = (Total Tests / Total Population) × 100

Confirmed-to-Test Ratio (Confirm/Test) This indicator reflects the proportion of tests that returned positive results:

- Confirmed-to-Test Ratio = (Total Confirmed Cases / Total Tests) × 100

Death-to-Confirmed Ratio (Death/Confirmed) Also known as the Case Fatality Rate (CFR), this measures the percentage of confirmed cases that resulted in death:

- Death-to-Confirmed Ratio = (Total Deaths / Total Confirmed Cases) × 100

Case-to-Population Ratio (Case/Pop) This metric shows the proportion of the population that has been confirmed as infected:

- Case-to-Population Ratio = (Total Confirmed Cases / Total Population) × 100

Death-to-Population Ratio (Death/Pop) This indicates the proportion of the population who died due to COVID-19:

- Death-to-Population Ratio = (Total Deaths / Total Population) × 100

3.3. Statistical methods

The study applies descriptive statistics, which summarize the characteristics of the dataset without attempting to draw conclusions beyond the data itself. The primary statistical techniques include:

- *Percentages and Ratios:* Used to standardize figures and allow meaningful comparisons across regions and time periods.
- *Comparative Analysis:* Examining Bangladesh's indicators relative to global averages to identify potential under-reporting, differences in testing strategies, or regional disparities.
- *Trend Analysis (Qualitative):* Observations about how COVID-19 testing and case counts declined significantly after April 2022, based on reported data.

No inferential statistical tests (e.g., hypothesis testing, regression analysis) were performed, as the focus of the study

was purely descriptive. All calculations were conducted using spreadsheet software, such as Microsoft Excel, ensuring that computations could be replicated for verification purposes.

4. RESULTS AND DISCUSSION

4.1. Deaths and cases within 2020 to 2023

By the end of 2023, Bangladesh had recorded 2,051,617 confirmed cases of COVID-19 and 29,499 related deaths, with the country's population during this period estimated at roughly 169.36 million (Figure 1). This translates to a case-to-population ratio of about 1.21% and a death-to-case ratio of 1.44%. While the fatality rate appears relatively modest when compared with the number of infections, it was still higher than the global average. Both confirmed cases and deaths reached their highest levels in 2021, marking the peak of the pandemic's impact in Bangladesh.

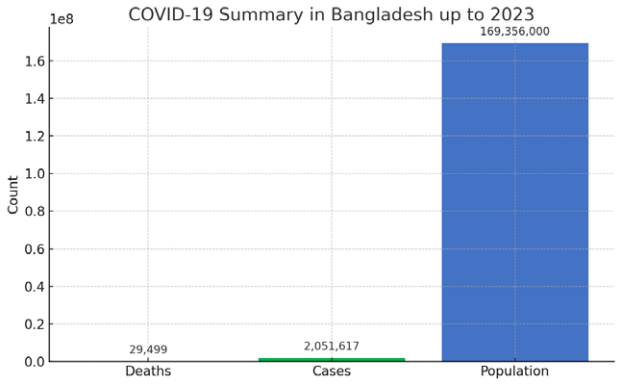

Figure 1. Deaths and cases within 2020 to 2023

Monthly trends in new COVID-19 cases showed sharp year-to-year fluctuations. In 2020, the outbreak began with only a handful of reported cases, but numbers climbed rapidly from May, surpassing 90,000 in both June and July. The situation intensified in 2021, which saw the steepest surges of the pandemic. April recorded 149,608 new cases, while July and August reached striking peaks of 276,229 and 328,902 cases, respectively. From 2022 onward, monthly case counts fell sharply, suggesting that stronger control measures and reduced transmission had begun to take effect (Figure 2).

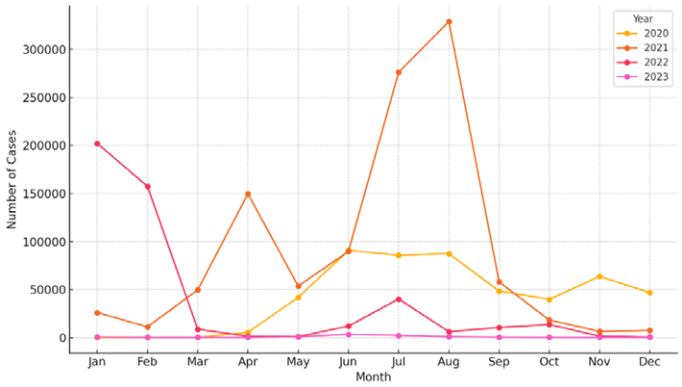

Figure 2. Month-wise comparison of COVID-19 cases within 2020 to 2023

4.2. Testing and case detection within 2020 to 2023

A total of 15,719,284 laboratory tests were conducted in the population of 169,356,000, corresponding to a testing coverage of approximately 9.28%. Among those tested, 2,051,775 cases were confirmed positive, resulting in a test positivity rate of 13.05% (Table 1).

Table 1. Testing and case detection within 2020 to 2023

Indicator	Value
Total Population	16,93,56,000
Laboratory Tests Conducted	1,57,19,284
Testing Coverage (%)	9.28%
Confirmed Positive Cases	20,51,775
Test Positivity Rate (%)	13.05%

Analysis of the temporal trends in COVID-19 data reveals a marked decline in both the number of laboratory tests conducted and the number of confirmed cases following April 2022 (Figure 3).

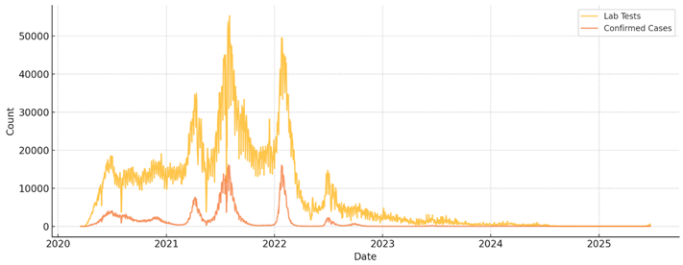

Figure 3. Test and case declining over time

Before this period, several distinct waves of infection were visible, each marked by sharp increases in testing and corresponding spikes in detected cases. After April 2022, however, testing volumes dropped to consistently lower levels, and the number of confirmed cases fell substantially alongside them.

4.3. Vaccination

An analysis of vaccination coverage indicates that over 84% of the population has received either the first or second dose of a COVID-19 vaccine, underscoring substantial progress toward widespread immunization (Figure 4).

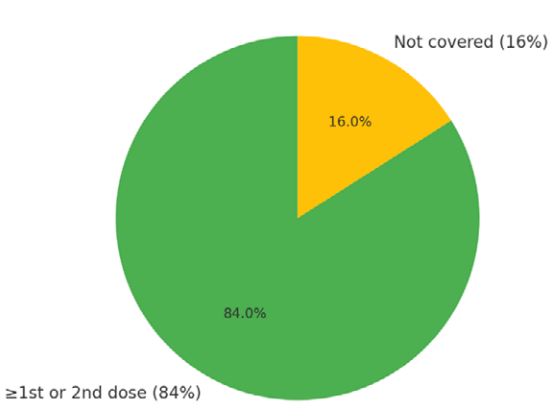

Figure 4. Vaccination among whole population

Sinopharm and Sinovac vaccines accounted for the majority of first and second doses administered, underscoring their central role in the early stages of Bangladesh's vaccination drive. In later phases, however, Pfizer and AstraZeneca became the primary vaccines used for booster doses — both the third and fourth shots (Figure 5).

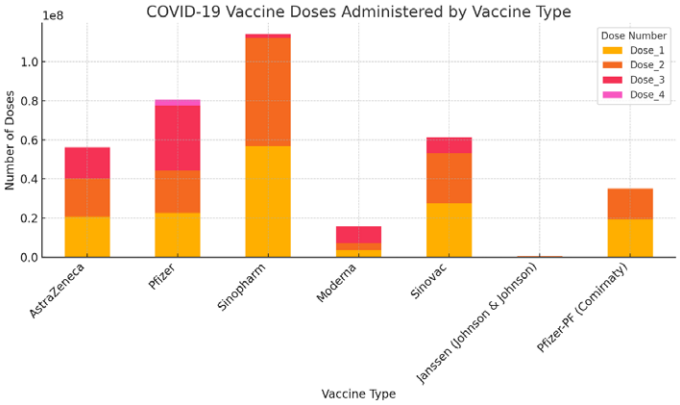

Figure 5. Type of vaccines

4.4. Division-wise vaccination

Table 2 summarizes COVID-19 vaccination coverage across Bangladesh's eight administrative divisions, showing the proportion of people who received first and second doses. Dhaka leads with the highest coverage, where 96.8% of residents received the first dose and 87.8% received the second. Other divisions, including Chittagong, Khulna, Sylhet, Rajshahi, Rangpur, and Barisal, also achieved relatively strong coverage, with first-dose rates ranging from roughly 83% to 89% and second-dose rates slightly lower, yet generally above 75%. Mymensingh division stands out with the lowest coverage, where only 70.2% received the first dose and 67.3% completed the second dose.

Table 2. Division-wise COVID-19 vaccination coverage in Bangladesh (%)

Divisions	1st dose (%)	2nd dose (%)
Dhaka	96.8	87.8
Chittagong	88.9	85
Khulna	85.6	82.1
Sylhet	85.5	82
Rajshahi	84.7	81.3
Rangpur	84.4	81.4
Barisal	83.1	75.9
Mymensingh	70.2	67.3

4.5. District-wise vaccination

District-level vaccination data show very high coverage for the initial doses, though some figures suggest vaccination of populations beyond official registries. For instance, Gazipur reports a first-dose coverage of 134% and a second-dose coverage of 116%, likely reflecting doses given to migrants or residents from neighboring areas. Chuadanga, while lower for the first and second doses compared to Gazipur, stands out with the highest third-dose uptake at 62%. In contrast, districts such as Chittagong and Dhaka show more modest third-dose coverage, around 36%. Fourth-dose administration remains minimal across the country, ranging from just 1% to 3% in most districts. Among the top ten districts for second-dose coverage, Gazipur leads at 116%, followed by Narayanganj (95%), Chittagong (91%), Chuadanga (90%), and Dhaka (89%). The other top-ranking districts also maintain rates well above the national average. On the other hand, the bottom ten districts lag considerably: Jhalokati reports the lowest coverage at 71%, followed by Shariatpur at 73%, with Barisal, Pirojpur, and Rangamati around 74% (Table 3).

Table 3. District-wise vaccination ranking

Top-most 10 district	
District	**% 2nd dose**
Gazipur	116
Narayanganj	95
Chittagong	91
Chuadanga	90
Dhaka	89
Brahmanbaria	89
Kishoreganj	88
Maulavi Bazar	87
Panchagarh	87
Manikganj	85
Bottom-most 10 district	
Jhalokati	71
Shariatpur	73
Barisal	74
Pirojpur	74
Rangamati	74
Madaripur	75
Bandarban	76
Bhola	77
Sunamganj	77
Naogaon	78

4.6. Discussion

The COVID-19 pandemic highlighted major challenges for low- and middle-income countries (LMICs) like Bangladesh, where limited healthcare infrastructure, economic pressures, and uneven access to services strongly influenced how the crisis unfolded. This study set out to examine trends in testing, mortality, and vaccination across the country, with the goal of understanding how these factors interacted in shaping the national response and identifying key areas where policy and health system improvements are needed.

4.6.1. Testing and case detection

The results show that Bangladesh did approximately 15.7 million laboratory tests by 2023, covering about 9.3% of the population. While this represents a substantial effort to expand diagnostic capacity, still remains low when compared with many developed countries, some of which achieved above 50% (Hale *et al.*, 2021). The relatively short coverage reflects common challenges faced by LMICs, including heavy dependence on less sensitive rapid antigen tests, limited PCR availability, and testing facilities concentrated in urban areas (Anwar *et al.*, 2020). This urban focus likely contributed to under-detection in rural districts reducing the accuracy of disease surveillance.

The drop in testing and case detection after April 2022 mirrors global trends, where easing restrictions and lower public concern decreased demand for tests (Hale *et al.*, 2021). But this decline may also have been influenced by resource reallocation and pandemic fatigue in countries like Bangladesh. The test positivity rate (13.05%) is relatively high, suggesting that testing was often targeted toward symptomatic individuals, which may have underestimated the true scale of infections. These observations reinforce concerns noted by Kavanagh *et al.* (2020) about underreported cases in LMICs and highlight the importance of decentralized testing and stronger surveillance systems to improve readiness for future outbreaks.

4.6.2. Mortality patterns

Between 2020 and 2023, recorded 29,499 COVID-19 deaths were recorded in Bangladesh with over two million confirmed cases, (case fatality rate (CFR)) of 1.44%. Although this rate seems moderate, it was higher than the global average for the same period, pointing to vulnerabilities in the healthcare system. Limited critical care capacity, shortages of oxygen, and hospital overcrowding during peak waves likely played a role in these outcomes (Walker *et al.*, 2020; Shammi *et al.*, 2020).

Bangladesh's relatively young population may have helped keep mortality lower than it might have been, since younger people generally experience less severe disease (Dowd *et al.*, 2020). Nonetheless, underreporting of deaths, particularly in villages remains a concern. Mortality surveillance in many LMICs is often incomplete, potentially masking the true face of disease (Shammi *et al.*, 2020). Strengthening these systems is important for better pandemic readiness and for achieving accurate assessments of health crises in the future.

4.6.3. Vaccination coverage and disparities

Data shows that Bangladesh has made significant progress in its COVID-19 vaccination campaign, with over 84% of the population receiving at least one dose. Achieving this level of coverage means a significant public health effort, given the country's resource limitations and logistical shortcomings. Early phases of the campaign relied mainly on Sinopharm and Sinovac vaccines, while later booster doses were mainly Pfizer and AstraZeneca, reflecting a diversified approach to vaccine procurement and rollout.

Despite these gains, regional differences in crisis management remain evident. Dhaka division achieved the highest vaccination rates, whereas Mymensingh lagged behind. These differences are consistent with previous studies highlighting urban-rural divides in vaccine access, shaped by factors such as infrastructure gaps, logistical barriers, education levels, and vaccine hesitancy (Paul *et al.*, 2021; Jannat *et al.*, 2024). Higher coverage in cities likely reflects both better healthcare access and more awareness campaigns, while rural communities continue to face challenges.

Interestingly, some districts reported vaccination coverage more than 100%, particularly for the first and second doses. Gazipur, for example, shows such anomalies, likely reflecting vaccination of populations beyond official residency counts, including migrant workers or people from nearby regions. These patterns highlight the challenges of tracking vaccination in mobile populations and underscore the need for robust data systems to accurately monitor distribution and coverage.

Finally, third and fourth dose coverage remains low in most districts. This may indicate waning interest in boosters or a perception that additional doses are less urgent as people were less affected by Covid after 2022. Such gaps left vulnerable groups at risk, particularly if new variants emerge, emphasizing the importance of targeted booster campaigns and ongoing public health engagement.

4.6.4. Implications and future directions

This study contributes valuable insights into Bangladesh's COVID-19 experience, highlighting successes in vaccination rollout despite challenges, as well as gaps in testing coverage and reporting of deaths. The observed disparities in vaccination coverage and the decline in testing raise critical questions for future preparedness.

Policy recommendations emerging from these findings include:

- Strengthening testing capacity to ensure timely detection and response, particularly in rural areas.
- Enhancing mortality surveillance systems to reduce underreporting
- Addressing logistical barriers in vaccination delivery to close regional gaps, particularly in divisions like Mymensingh.
- Sustaining public communication campaigns to combat vaccine hesitancy and encourage people to take booster dose.
- Improving data systems to capture accurate data and account for mobile population such as migration worker.

While this study relies on descriptive statistics, future research could employ inferential techniques or modeling approaches to assess causal relationships, eand evaluate long-term health impacts of the pandemic in Bangladesh.

4.6.5. Limitations

It is important to note several limitations of this study. Firstly, the analysis relies on secondary data from government dashboards and international agencies, which may be affected by reporting biases or inconsistencies in data quality. Secondly, the descriptive approach used here does not allow for any cause & effect relationship. Finally, the study does not capture qualitative aspects, such as community perceptions or healthcare worker experiences, which could provide deeper insight into the observed trends and findings.

5. CONCLUSION

This study provides a detailed assessment of COVID-19 trends

in Bangladesh, highlighting testing capacity, mortality patterns, and vaccination coverage. By examining national indicators alongside regional and district-level disparities, the analysis sheds light on structural factors and health system limitations during the pandemic.

The findings reveal the impact of uneven resource allocation. Even with notable national progress in vaccination, substantial inequities remain between regions and population groups. Testing coverage remaining below 10% of the population, coupled with a high positivity rate, suggests that many infections went unidentified, complicating efforts to control the virus. Similarly, the considerable variation in vaccination uptake across divisions and districts points to ongoing challenges in achieving equitable access, despite overall immunization successes.

District-level issues, such as coverage exceeding 100% in certain areas, further highlight the challenges posed by population mobility and the complexities of tracking public health interventions. These insights can inform future programs, emphasizing the need to account for migration patterns and regional disparities in health infrastructure.

Overall, the study underscores the importance of strengthening decentralized health services, building resilient surveillance systems, and maintaining public trust to enhance preparedness for future health emergencies. Bangladesh's experience offers both cautionary lessons and practical guidance for other LMICs seeking to balance rapid pandemic response with equitable healthcare delivery.

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