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Did national holidays accelerate COVID-19 diffusion during the first phase of the pandemic in Bangladesh?

Mohammad Radid Khan[1], Sayem Mottakin[2], Md. Ahsan Kabir[2], Md. Enamul Hoque[3], Mohammad Ruhul Amin[4], Md. Harunur Rashid[5], Md. Shariful Islam[5]
[1]Department of Biochemistry and Microbiology, North South University, Dhaka, Bangladesh
[2]Department of Electrical and Computer Engineering, North South University, Dhaka, Bangladesh
[3]Department of Physics, Shahjalal University of Science and Technology, Sylhet, Bangladesh
[4]Department of Computer and Information Science, Fordham University, New York, USA
[5]Department of Mathematics and Physics, North South University, Dhaka, Bangladesh

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ABSTRACT

Bangladesh registered 20,117,32 confirmed cases of COVID-19 and the death toll crossed the grim milestone of 29,323 across the country as of August 31st, 2022. Despite the enforcement of stringent COVID-19 measures, the country witnessed an accelerated diffusion of coronavirus cases during the national events, inclusive of short festivals, in 2020. The present study aims to examine the association between these national holidays and the COVID-19 trasmission rate in Bangladesh. We employed a mathematical model and calculated the instantaneous reproduction number, R_t, of the 64 districts in Bangladesh to check the dynamics of COVID-19 diffusion. The comprehensive analysis shows a notable escalation of R_t value and thus the enhanced transmission rate in Dhaka and in all industrialized cities during the major events such as, garments reopening and religious holidays in Bangladesh. We further showcase the COVID-19 diffusion explicitly in Dhaka Division at the first phase of the pandemic in Bangladesh. Based on our analysis, a set of measures, including restricted public mobility and the celebration of festivals, alongside improving the public's awareness of the situation, has been recommended to evade the future pandemic risks while running the national festival activities in Bangladesh.

Corresponding Author:

Md. Shariful Islam
Department of Mathematics and Physics, North South University
Block B, Bashundhara RA, Dhaka-1229, Bangladesh
Email: shariful.islam10@northsouth.edu

1. INTRODUCTION

Ever since the end of 2019, the world has been afflicted by coronavirus disease 19 (COVID-19), which is caused by the severe acute respiratory syndrome coronavirus (SARS-CoV-2019) [1]. This deadly virus has wreaked havoc upon the global population and has already taken the lives of 6.49 million people as of late August 2022 [2]–[5]. Soon after the Bangladeshi capital city of Dhaka began experiencing the first wave of COVID-19 in early March 2020, the local government announced the first lockdown near the end of March 2020, to mitigate the diffusion of the virus [6]. The stringent lockdown played a pivotal role in reducing the COVID-19 transmission at the initial stage of the pandemic, with the criticality of this restriction becoming quickly apparent, considering the current socio-economic status of Bangladesh [7]. Therefore, the government seemingly prioritized the economy [8], during the earlier stages of the pandemic,

and evidently decided to adopt a flexible lockdown system with the gradual opening of all industries and sectors of commerce, apart from educational institutions [8]. Since Dhaka, the capital of Bangladesh, one of the most crowded cities in the world, carries up to 35% of the country's economy [8], it is not surprising why Dhaka became the epicenter of the current pandemic. Besides this metropolitan city, its surrounding areas including Gazipur and Narayanganj also hold financial significance as important industrial zones. Multiple lines of evidence also reported the high diffusion of coronavirus in these domains in 2020 [9]. Holiday periods can be considered to escalate the COVID-19 transmission as travelling via regular transports enhances the risk of getting infected [10], [11]. Moreover, social behavior of individuals fluctuates during holidays which might have a positive impact on COVID-19 diffusion rate, as reported previously [12]–[14]. Notably, Plümper *et al.* [15] performed an ecological analysis of variations on weekly COVID-19 positive cases across Germany and demonstrated the positive impact of the six weeks long summer school holiday on the pandemic [15]. However, this study considered only the long summer school holiday, while the impact of various short holidays (Christmas holiday) on coronavirus transmission rate has been overlooked. Unfortunately, the socio-economic structure of Bangladesh does not allow its masses to have 4-6 weeks long holidays at a time in one calendar year and thus, it is important to check the significance of short holidays, even if it is 1-3 days, on the pandemic.

The aim of this study is to examine the impact of short holidays on the pandemic in Bangladesh. To investigate this, we look at the dynamics of R_t, the instantaneous reproduction number, over time in Dhaka and Chattogram division, two business hubs of Bangladesh. Furthermore, this study assesses the pandemic situation in tourist spots during short holidays. An epidemic will occur if R_t value is greater than 1, whereas the number of cases will drop when $R_t<1$ [16]. The R_t values provide quantitative real-time feedback that represents how the population being observed is faring under present conditions. As such, varying the conditions through various means, often government-imposed regulations such as lockdowns, having to wear masks when outdoors, and so on, will allow to see trends in the R_t values that show the effectiveness of tactics in place.

The calculated R_t values from our comprehensive analysis illustrate a spontaneous trend of COVID-19 cases particularly in Dhaka division, regardless of the pandemic situation in other districts, while observing the mass movement due to the major national events in Bangladesh. Notably, the R_t value goes over 1 on multiple occasions in Dhaka and a few other cities during major events or festivals such as garments factories reopening time, Eid Ul-Fitr and Eid Ul-Adha (religious holidays for Muslims) in 2020.

2. RESEARCH METHOD

The basic reproduction number (R_0) defines the transmissibility of the disease. It is the mean of the variable number of secondary infections brought about by the primary infection, in a totally susceptible population [16]. When $R_0>1$, an epidemic will occur within the population. However, realistically, populations will rarely be totally susceptible, for a myriad of reasons [17]. The effective reproduction number (R_e) accounts for this assumption made by the basic reproduction number and calculates an adjusted value. When it is calculated in real-time, for time "t", it is referred to as instantaneous reproduction number, R_t. To describe the diffusion of coronavirus transmission during the short holydays in Bangladesh, the instantaneous reproduction number, Rt, has been monitored as it provides the real-time estimation of the pandemic dynamics and instantaneous effect of the control mechanism. In contrast to the R_0 and R_e, the R_t value represents the average number of secondary infections per primary case at real time measure on a daily basis.

When $R_t>1$, an epidemic will occur. If $R_t=1$, then the number of cases is stable, whereas the number of cases will start dropping when $R_t<1$ and the disease eventually ceases to be an epidemic or endemic. This study calculates the R_t values for the 64 districts of Bangladesh including the Dhaka and Chattogram Division and analyses the results to identify the trends with respect to various major events and festivals. The R_0, and R_e values are calculated by the following formulas:

$$R_0 = \frac{\beta}{\mu+\gamma} \quad (1)$$

Where β, γ, μ represents infection rate, death rate, and recovery rate respectively. R_e can be written as,

$$R_e(t) = R_0 \frac{S(t)}{N} \quad (2)$$

From the SIRD model [6], we know that,

$$\frac{dI(t)}{dt} = \frac{\beta}{N} S(t)I(t) - \gamma I(t) - \mu I(t) \quad (3)$$

With the help of (3), when $I=I_{max}$, it can be derived that $S(t)=N/R_0$ and $R_e=1$.
Here, "t", "S", and "N" denote time "t", susceptible population, and total population respectively, whereas random walk is represented by θ, and γ' varies independently [6].

To calculate R_t, we establish a link between the initial number of confirmed cases (y_j) and the number of cases of a previous day, right before a specific T_s. We can equate this idea as shown below:

$$y_j = y_{(j-T_s)} \times (1 + r) = y_{(j-T_s)} \times exp\ exp\ [(R_t - 1)j\ /\ T_s] \quad (4)$$

$$C' = Ce^{\gamma'(R_t-1)} = Ce^{\theta} \quad (5)$$

Here, γ' varies independently, while random walk is observed by C=y_j and $\vartheta = \gamma'(R_t - 1)$. The term "serial interval" (T_s) refers to the length of time that passes between subsequent cases in a series of transmissions of a particular disease. Thus, solving the above equations, R_t can be written as:

$$R_t = \frac{\theta}{\gamma'} + 1$$

It is important to be able to calculate the instantaneous reproduction number, since monitoring its value and comparing it with the ratio between the total population and the susceptible population in the early stages will tell us when the ensuing pandemic goes beyond our control [6].

2.1. Data visualization

This study uses Python, Pandas, GeoPandas, Spyder IDE, and ArcMap to build the map. Python [18] is embedded into Geographical Information System (GIS) applications for this study. ArcMap [19] is applied to create, edit, and view geospatial data. GeoPandas is a Python module based on the Pandas library that makes it easier to work with spatial data. We have taken the spatial map of Bangladesh from HDX (The Humanitarian Data Exchange) and separated the 13 districts of the Dhaka division from the downloaded shapefile using ArcMAP. Here, each District is represented in the form of a single polygon in a shape file and it was converted into a Geopandas GeoDataFrame. We converted the data collected from the CSV file into a Pandas DataFrame and performed a join operation in python to combine both the GeoDataFrame and DataFrame into one GeoDataFrame. Lastly, by using the GeoDataFrame, we visualized the map using ArcMAP software.

R_t values for different districts were calculated by using Python and the collected data were visualized in R [20], with RStudio as the IDE. With the help of the package "ggplot2", graphs of R_t vs time were plotted for all 64 districts of Bangladesh. Finally, with the help of the "cowplot" package, the individual graphs were all combined into multi-plot graphs.

3. RESULTS

3.1. Diffusion of COVID-19 at the first phase of pandemic in Dhaka division

To explore the diffusion of coronavirus, first we checked the number of infected cases in Dhaka division over time as this zone carries major economic significance. At the beginning of March 2020, only 2 out of the 13 districts, that is, the capital Dhaka and the neighboring Narayanganj, were infected with COVID-19 as shown in Figure 1. However, the disease spread quickly within the Division in the oncoming months due to Dhaka district being the primary commercial hub of the region, and thus deeply economically connected to the bordering districts. During April and May, rapid transmission occurred within the northern Districts such as Gazipur and Narsingdi, only to then disseminate much more swiftly throughout the eastern and southern ones, namely Manikganj, Rajbari, Faridpur, Gopalganj, Madaripur, and Shariatpur, in June, as reflected by the number of cases per 10,000 as shown in Figure 1. Eventually, the total number of new cases throughout Dhaka Division peaked around the first week of July at~1,050 cases. The overall situation in the various Districts during August 2020 remained similar to July. Notably, it was only in September 2020 that the conditions improved in the Division, primarily in the eastern and southern districts such as Faridpur, Gopalganj and Shariatpur, with the gradual improvements making their way into the other districts, namely Manikganj, Rajbari, and Madaripur, during October 2020 as well. We speculate that the enforcement of several stringent measures including wearing masks, maintaining social distance, and extending the lockdown by 66 days are associated with the strongest and most widespread attenuation of COVID-19 cases in Bangladesh. However, even in October, the state of affairs in Dhaka district remained at an alarming level see in Figure 1. To understand more clearly how the disease spread throughout the division, next we aim to examine the dynamics of R_t values during this period in Dhaka division.

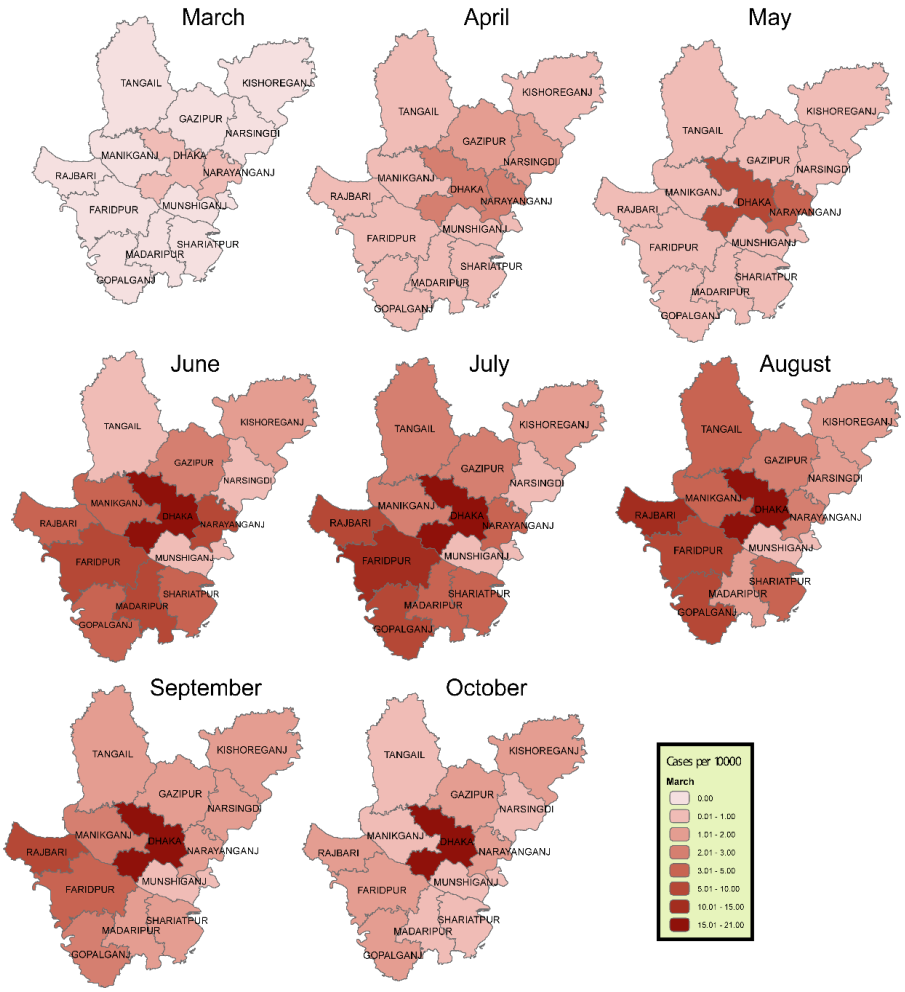

Figure 1. Propagation of COVID-19 from March 2020 to October 2020 in Dhaka Division

3.2. R_t dynamics of COVID-19 in Dhaka Division during national events

Bangladesh has witnessed the occurrence of new local outbreaks during the national holidays in 2020. We hypothesize that these outbreaks are associated with the increased inter-regional mobility and thus increase the effective reproduction number (R_t). To examine the evolution of the R_t values in Dhaka Division, a segmented regression analysis has been performed for the first eight months (March 2020-October 2020) of the pandemic. While the R_t value for Dhaka and Gazipur districts stayed above 1 for the majority of the duration (eight months) covered by our data, the same cannot be said for the rest of the Division as presented in Figure 2. Apart from these two, all other districts maintained an R_t value of less than 1 throughout the time period being investigated, with peaksand throughs spread out primarily around major events, such as when garments reopened (Major event 2), Eid-ul-fitr (Major Religious Festival 1), and Eid-ul-Adha (Major Religious Festival 2). Mass-testing with RT-PCR kits began a couple weeks after the first lockdown (Major Event 1), in Dhaka [21], followed by other districts [7], [21], which is reflected by the spikes in the R_t values for these districts in mid-April or soon after. Similarly, since testing began at different times in the rest of the districts, they show spikes in their values much later, in the following months. Dhaka, Gazipur, and Narayanganj comprise the primary locations of the garments factories in the Division. Initially, before Major Event 1 (ME1), none of the districts had any R_t values because of unavailable data. However, after the ME1, some districts experienced a large spike in R_t values, with the way being led by Dhaka, Gazipur and Narayanganj as shown in Figure 2. The R_t value for Dhaka rapidly decreased leading up to Major Event 2 (ME2), only to increase again afterwards. For Gazipur however, the R_t values increased leading up to ME2 followed by an attenuation trend afterwards. On the other hand, the R_t values started decreasing right before ME2, and kept doing so afterwards in Narayanganj. These spontaneous characteristics of R_t values reflect the COVID-19 transmission as a result of the mass workers moving throughout the districts to get to their workplaces as soon as they opened.

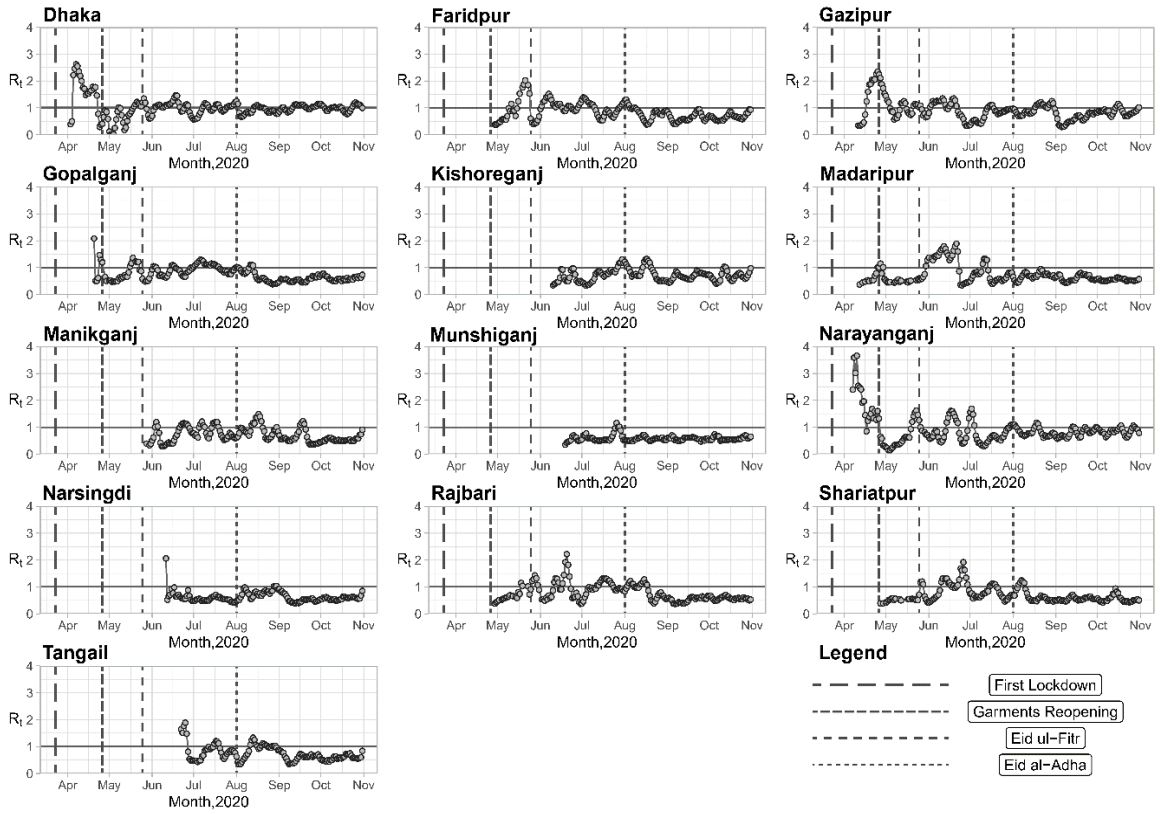

Figure 2. Comprehensive analysis of R_t values over time March 2020 to October 2020 in Dhaka division

Now, when it comes to Major Religious Festival 1(MRF1), Dhaka had a slight rise, followed by a significant drop, and then a large increase in R_t values as shown in Figure 2. The decrease brought it to below 1, while the final increase left it much higher than 1. It was very similar for every other district with varying degrees of decreases and increases with a notable exception of Faridpur, showing a surge of R_t in the moments before the MRF1. Apart from these, a few other districts such as Munshiganj, Kishoreganj, Tangail and Narsingdi did not have any R_t data at this time period. For Major Religious Festival 2 (MRF2), every single District had an increase in R_t values until just before, or right after the day of MRF2. Notably, we have also noticed a significant fall off followed by a moderate or sharp elevation of R_t that brought the majority of the districts above 1 again, such as Dhaka, Gazipur and Kishoreganj. However, the escalation was temporary for most districts as they soon returned to below 1. Even Kishoreganj, which had a surge, experienced a rapid attenuation of R_t values. These findings are supported by the trends in the number of cases, which indicate, for example, that Dhaka district experienced an overall leap of over 200% in the number of cases in the weeks before and after MRF1. Similarly, the other districts such as Gazipur and Narayanganj also witnessed escalations in cases upwards of 500% during the same timeframe. These trends might insinuate that people moved to their hometowns to celebrate the festivals with their families, and thus, resulted in a spike in the number of cases, and consequently R_t values, during such events.

3.3. Evolution of R_t values in chattogram division at the time of national events

Next, we check the trend of R_t values in Chattogram division during the national events. To do that, another R_t multiplot has been made by using the data from the 11 districts of Chattogram division. One of these 11 districts, Bandarban, did not have any available data throughout the time period investigated in this paper. Both Cox's Bazar and Chattogram districts experienced significant spikes in their R_t values as shown in Figure 3. The rest of the districts manifested similar trends, with varying fluctuations. Strikingly, we also observed a spontaneous trend of R_t values in other major cities including Mymensingh, Sylhet, Pabna and Jaipurhat in the course of Garments reopening events Figures 4 and 5. Moreover, the comprehensive analysis illustrates a surge of R_t value (~1.8) in Barisal district, and others, during the MRF1 in Figures 4 and 5. Furthermore, as can reasonably be expected, we note the significant surge of over 500% in the number of cases in Chattogram district in the weeks before and after MRF1. Similar developments have been observed in the other districts of Chattogram division, including but not exclusively, Brahmanbaria, and Cox's Bazar.

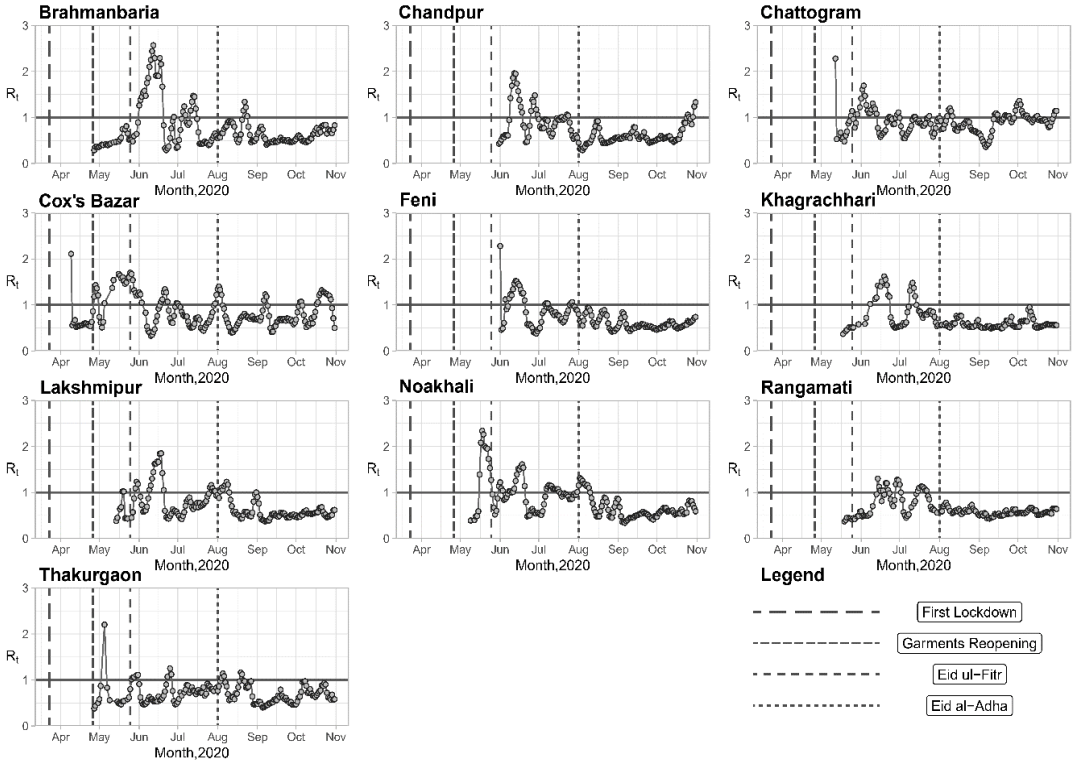

Figure 3. Dynamics of R_t values over time March 2020 to October 2020 in Chattogram Division

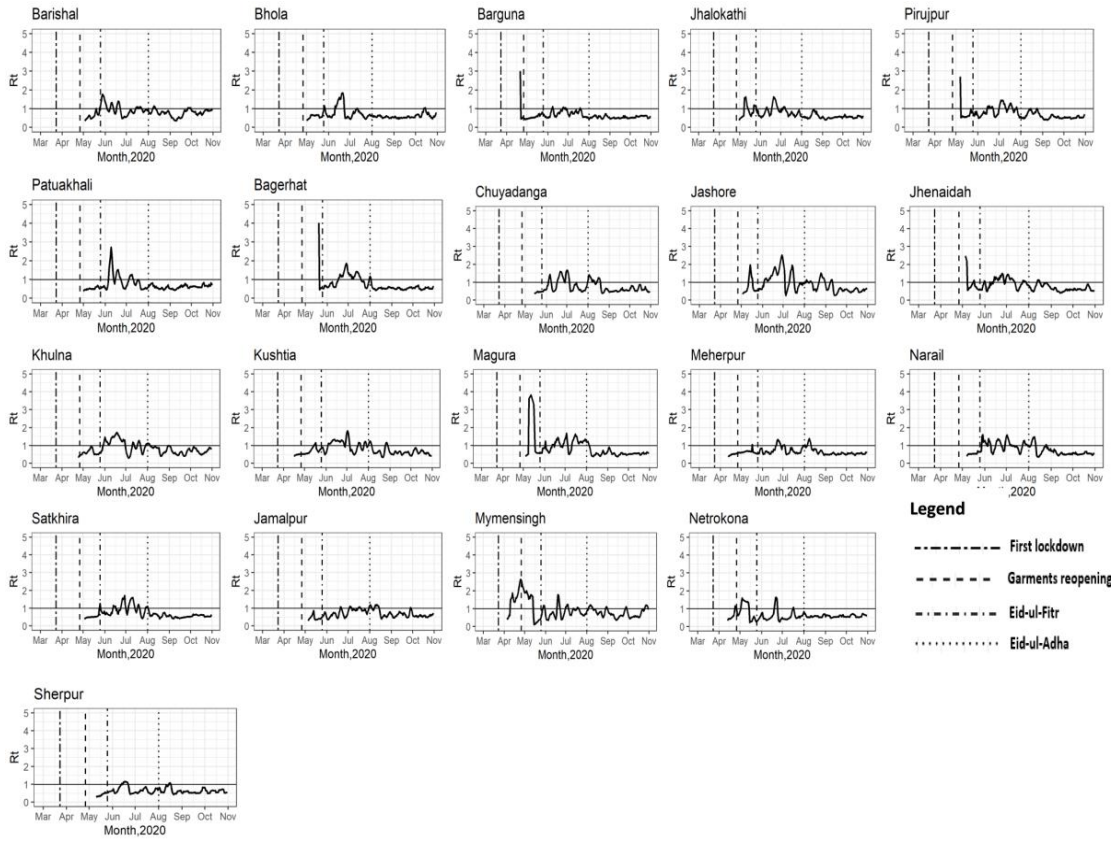

Figure 4. Dynamics of R_t values over time March 2020 to October 2020 in Barisal, Khulna, and Mymensingh Divisions

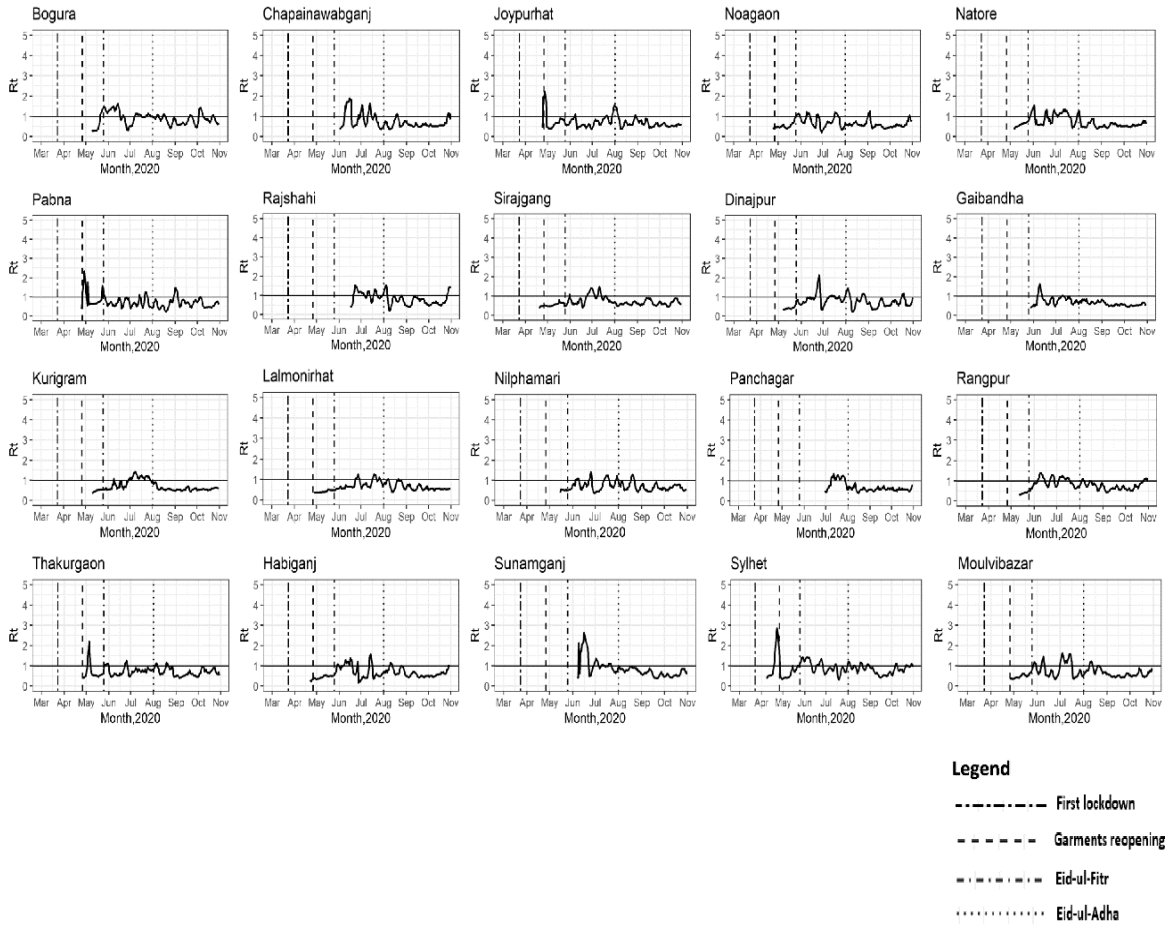

Figure 5. Dynamics of R_t values over time March 2020 to October 2020 in Sylhet, Rajshahi, and Rangpur divisions

4. DISCUSSION

While the COVID-19 pandemic has shaken all the countries throughout the globe to their very roots While the COVID-19 pandemic has shaken all the countries throughout the globe to their very roots [4], [22], the responses of individual nations to such a novel threat to humanity has varied greatly [23]. Even when we look at the countries in the South Asian region, including Bangladesh, measures taken against the pandemic have differed significantly in different phases [24]. Multiple lines of evendence suggest that long holiday periods can play a pivotal role to accelerate the COVID-19 transmission rate because of frequent social gathering and increased mass mobility in a country [24]. The low- and middle-income countries (LMIC) of the South-Asian region also experienced mass mobility of internal migrants from the major cities to its peripheral region during the national festivals or short holidays in 2020 [24]. This study aims to disentangale the impact of short holidays on COVID-19 diffusion in Bangladesh by scanning the instantaneous reproduction number over time. Notably, we observe a significant surge of corovirus cases across major cities that were or had been on short holiday. While the COVID-19 infected numbers represented the entire country, it was the commercial hubs of the nation that suffered the most, both economically and rate-of-infection-wise, as foreseen by Islam *et al.* [25]. The primary industry in the division is the RMG sector, operating mostly from Dhaka, Narayanganj, and Gazipur where the majority of employees originate from other districts, having moved to these industrial zones for work [24]. Therefore, when the government officials decided to impose the first lockdown in late March 2020, most of these out-of-district workers, their families, or both, relocated back to their hometowns [6], [24].

As a result, such high mobility of individuals led to greater risks of transmitting the virus. This explains the spikes in Rt values for Dhaka, Gazipur, and Narayanganj right after the first lockdown. Similar trends were observed when there was similarly high mobility among the masses during the holidays accompanying Eid ul-Fitr and Eid al-Adha, which further explains the drastic leaps in the number of cases in both Dhaka and Chattogram division over the same timeframe [24], [26], [27]. Moreover, Dhaka is the major

financial hub of the country and all the major commercial trade routes go through it. Hence, there is a constant influx of masses of people and transport both into and out of the district all the time. Due to its high physical communication with the rest of the districts, as well as the country, transmissibility of the virus is greatly heightened. This further leads to increases in the Rt of Dhaka district, as well as the rest of the districts. Chattogram district and Cox's Bazar district are both important economic zones in the division, with the former being the primary port city in the country, and the latter being a world renown tourist hotspot. As such, both locations observed a rapid increase in the mobility of the population to and from the districts right before and after the major events and major religious festivals, be it for tourism or for the gradual revival of various other industries [28], [29]. This resulted in both districts showing spikes in their Rt plots, as well as in the number of positive cases, during these times. The spikes (Rt value~1.6) are especially prominent for Cox's Bazar as the major events and religious festivals are often accompanied by relatively lengthy (3-5 days) national holidays, which further encourage mobility among the masses. We speculate that such surges in the number of cases and Rt are more pronounced in such financial hubs due to a greater influx of individuals into these districts, from the others, where the majority went to congregate for the holidays. However, despite the reliability of the mathematical techniques used in this study, we have no way to account for small numbers of superspreaders who propagated disease transmission while travelling against the general flow of the populace. Though a more accurate analysis could be done with the data of individual mobility, such confidential statistics remain beyond the scope of this study due to privacy concerns.

Despite the first cases of COVID-19 being detected in the division on March 8th, 2020, the first lockdown was only imposed on March 23rd, 2020. Therefore, if the lockdown were imposed sooner, the transmission of the disease throughout the country could have been minimized as reported previously [8]. Furthermore, there is a lack of adequate data for most districts and divisions before the major festivals, due to an inadequate supply of testing kits, alongside widespread unwillingness to participate in tests [21]. Even after the end of the initial waves of 2020, India had also been experiencing a sudden rise in COVID-19 transmission because of minimal lockdowns being imposed by the Indian government during the first half of 2021, while allowing celebration of religious festivals, alongside political rallies, with effectively no hindrance [30]. In both countries, unrestricted mobility of the general population, together with asymptomatic victims of the virus, lead to the disease spreading rapidly through the respective populations, primarily during the numerous holidays of varying lengths. Similar studies, including those by renowned institutes such as the Robert-Koch-Institute [10], [12], [15] have also shown how such holidays have resulted in the heightened transmission of the virus, with asymptomatic patients often bringing it across borders. Therefore, an evidence-based approach and contextual strategies should be adopted to avoid the COVID-19 diffusion during future festivals. On the other hand, despite the numbers of experts constantly attempting to alert the people about the risks of COVID-19, in order to help them understand the dire circumstances we find ourselves in, a significant portion of the masses refuse to even try to comprehend the present state of affairs, instead opting to publicly and aggressively demand their former unrestrained mobility, ignoring the directives issued by the government, as well as not bothering to get tested upon appearance of known symptoms of COVID-19 [7]. In addition to the Bangladeshi Government's prescribed current cautionary measures, we suggest taking the following interdisciplinary approaches and contextual policies to contain future pandemics while running the national festival activities, further building on those recommended by [6], [25]. Firstly, the closure and isolation of the major commercial hubs, such as Dhaka district, is crucial to limit the mobility of the general public and thus, minimize the spread of the disease to the neighboring districts. Secondly, government holidays for the national festivals must be kept at the bare minimum, since it has been observed that even holidays of moderate lengths lead to people going back to their hometowns, often carrying the virus with them. Similarly, a person might get infected when they visit their hometown and bring back the disease to their workplace after the holidays, further propagating the spread of the virus in the commercial zones. Thirdly, greater efforts must be made to raise awareness among the general populace in order to reduce misconceptions about the current situation, and make them more willing to take the necessary precautions to minimize the transmission of COVID-19.

5. CONCLUSION

While the COVID-19 pandemic has proven itself a unique challenge on a global scale, this was neither the first nor the last time the world would experience an issue so debilitating. While such calamities may come and go, it is imperative that we do not forget the lessons written in blood. Above all, we need to understand that this might be the beginning of a new humanitarian crisis and we likely will experience many more in the future. Therefore, if we do not upgrade ourselves to implement the best practices to save lives and do not learn the lessons from 2020, Bangladesh might experience another catastrophic situation in the near future.

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BIOGRAPHIES OF AUTHORS

Mohammad Radid Khan is currently an undergraduate student in the Department of Biochemistry and Microbiology, North South University. He is also a research assistant under the mentorship of Md Shariful Islam, of the Department of Mathematics and Physics, North South University. He is currently working on in silico mass-spectrometry based proteomics analyses and has expressed an interest in probing the mechanisms underlying various neurodegenerative diseases, and cancers; as well as modelling various biological systems to aid in further exploratory investigations. He can be contacted at this email: radid.khan@gmail.com.

Sayem Mottakin was born and raised in Dhaka. I have majored in Computer Science and Engineering with a concentration on artificial intelligence and machine learning from North South University, Dhaka. My areas of interest in research are bioinformatics, machine learning, and computer vision. He can be contacted at this email: sayem.mottakin@northsouth.edu.

Md. Ahsan Kabir is a business analyst with extensive experience and management Skills and works for a binsort business solution limited. The company develops and sells solutions that enable service providing quality one-step IT services solutions according to the customer needs, wants, and demands. As a business analyst, he is responsible for identifying strategic opportunities from data patterns by the company. In 2020, Md. Ahsan Kabir has a B. Sc in Computer Science and amp, Engineering from the North South University. He can be contacted at this email: ahsankabir719@gmail.com.

Md. Enamul Hoque is working as an associate professor at the Daprt of Physics, Shahjalal University of Science and Technolgy, Sylhet, Bangladesh. Dr. Hoque finished his in nonlinear optics and published his work in various reputed journal. Currently, he is working on nonlinear optics, mathematical modeling, and machine learning. He can be contacted at mjonyh-phy@sust.edu.

Mohammad Ruhul Amin is an assistant professor in the Computer and Information Science department at Fordham University. He obtained his PhD from the Computer Science department at Stony Brook University (SBU). He is involved in leading multiple collaborative research works in Bioinformatics and Social Science. During his internship at Amazon AWS AI Algorithms group, he developed deep learning based anomaly detection algorithms. At the moment, Dr. Amin leads a small research group in Bengali Natural Language Processing at Shahjalal University of Science and Technology, Bangladesh. He can be contacted at mamin17@fordham.edu.

Md Harunur Rashid is an assistant Professor of Department of Mathematics and Physics at North South University, Dhaka, Bangladesh. Before, he has been a Post Doctoral fellow at RMIT, Australia. He has published several peer-reviewed scientific articles in major journals on the subjects of molecular dynamics simulation. He can be contacted at email: harunur.rashid01@northsouth.edu.

Md Shariful Islam is currently working as a faculty at Dept. of Mathematics and Physics, North South University, Dhaka, Bangladesh. Dr. Islam is a Bio physicist working on mathematical modeling, proteomics, Artificial Intelligence (AI) to understand the puzzle of different diseases such as, Parkinson's Disease, and Heart-disease. His research aim is to understand the mechanism of LRRK2 and Alpha Synuclein protein in Parkinson's Disease by using Mass-spectrometry based proteomics and phosphoproteomics. Besides, He is also interested to explore different models by applying machine learning methods. He can be contacted at email: shariful.islam10@northsouth.edu.