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# Characteristics, Diagnosis, Treatments and Public Awareness of Covid-19 Pandemic in Bangladesh: Mathematical Analysis

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## Abstract

**Background:** The situation of Covid-19 in Bangladesh is analysed using a mathematical model. **Objective:** The objective of this study was the mathematical analysis and statistics of Covid-19 in Bangladesh which originates with reliable and perfect forecasts of the outbreak. **Methodology:** The Runge-Kutta method was applied to calculate the variables of the system of equations of the SEIRD compartmental model which was developed based on the SEIR model. Data of Covid-19 pandemic in Bangladesh were analyzed from March 08 to December 07, 2020. **Results:** The cumulative infection rate was used in the model to obtain the best fit with the available data. The statistics of Covid-19 in Bangladesh showed that the highest numbers of infections and deaths were observed in the 4$^{th}$ month (end of June) from the reported date those were consistent with other countries. We had also derived a reproduction number, $R_t$ for each day so that the model's result closely replicates the daily number of recently infected cases. Furthermore, the infected and death rate were observed highest among the age group of 31-40 and 61-above, respectively. **Conclusion:** This study contributes to a better understanding about the control policies of the Covid-19 pandemic in Bangladesh based on the estimated parameters of the proposed model and investigations of corona statistics. [*Bangladesh Journal of Infectious Diseases, June 2021;8(1):18-26]*

**Keywords:** Covid-19 pandemic; SEIRD model; basic reproduction number; Mutation

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## Introduction

The Covid-19 that began in Bangladesh in early March 2020 has now become a pandemic. In the last ten months, the confirmed cases of Covid-19 are quickly increasing in Bangladesh as well as infected cases have been noticed from all areas of the country. The Institute of Epidemiology Disease Control and Research (IEDCR) under the Ministry of Health and Family Welfare (MFHW) in Bangladesh is responsible for researching and controlling epidemiological and infectious diseases, such as the Covid-19 outbreak in Bangladesh. However, Bangladesh did not have a remarkable health policy and governmental structures to fight against the Covid-19 pandemic. Initially, in response to the Covid-19 pandemic, the Government of Bangladesh declared the enforcement of lockdown from March 26 and extended it up to 30 May 2020 in seven different time slots. As of 31 May 2020, after the 65 days of lockdown, Dhaka was normal as usual where no social distancing or any health guideline was maintained. World Health Organization (WHO) suggested several preventive measures which comprise washing hands with water and soap regularly for at least 20 seconds, avoiding touching the eyes, mouths, or nose with dirty hands. Recent research made some recommendations on how Bangladesh could fight Covid-19[1]. Still now, the researches and analyses about the coronavirus in Bangladesh have been conducted on a limited scale and also lack reasonable estimates of the pandemic. In this write-up, we briefly eloquent the present situation of Covid-19 in Bangladesh and highlights some recommendations on what way the country can predict and overcome the pandemic.

Various studies have presented for forecasting many epidemic diseases using compartmental models to estimate the transmission parameters, basic reproduction number, peak point[2-7]. Among them, Anwar et al[2] used the SEIR model to predict the active Covid-19 cases in India based on the effect of countrywide lockdown and estimated the peak period and sizes of active infected cases. The epidemic peak for Covid-19 using real-time data based on basic reproduction numbers in Japan was estimated by Kuniya[3]. The Poisson model with time-dependent transmission was proposed by Hong and Li[4] and removal rates to account for probable arbitrary errors in reporting and evaluation of a time-dependent reproduction number. Good agreements between reported data and the results of the SIR model were observed[5-6] and they also provided some future predictions. The epidemic outbursts were examined applying the SIR model and gave some outlines of the controlling system[7]. Besides, Chatterjee et al[8] used the SIRD model and simulated aiming features of the infection in India and some other countries. The study[9] observed in their investigations that following partial lockdown with business and economic activities with social distancing and WHO guidelines could be the best policy to retain Covid-19. So, as far, nontherapeutic interventions to reduce the spread of the virus are the most effective measures yet.

This article, therefore, focuses on the mathematical analysis, presents some statistics and the strategic managing system of the Covid-19 pandemic in Bangladesh. This paper is structured as in section 2, a mathematical model is described. Section 3 highlights the data analysis, model validation, and pandemic statistics. Characteristics of coronavirus, including mutation, diagnosis, and treatments are conferred in section 4. Finally, results and conclusions are drawn in section 5.

## Methodology

**Model equations:** Following the SEIR model, we develop a model that is signified by SEIRD. The SEIRD model has five compartments those are *S* (Susceptible), *E* (Exposed), *I* (Infective), $R_e$ (Recovered) and *D* (Death). Thus, $N = S + E + I + R_e + D$ shows the total number of people. A new compartment *D* is added with the SEIR model, which contains individuals who are infected and death. The model is mentioned in below by the coupled of ordinary differential equations.

$$\frac{dS}{dt} = -\beta S(\varepsilon_1 I + \varepsilon_2 E) \qquad \text{Equation No. 1}$$

$$\frac{dE}{dt} = \beta S(\varepsilon_1 I + \varepsilon_2 E) - \gamma E \qquad \text{Equation No. 2}$$

$$\frac{dI}{dt} = p\gamma E - (\mu + \delta) I \qquad \text{Equation No. 3}$$

$$\frac{dR_e}{dt} = \delta I + (1-p)\gamma E \qquad \text{Equation No. 4}$$

$$\frac{dD}{dt} = \mu I \qquad \text{Equation No. 5}$$

with the initial conditions $S(0) = S_0, E(0) = 0, I(0) = I_0, R_e(0) = 0, D(0) = 0$

The symbols $\varepsilon_1$ and $\varepsilon_2$ represent the coefficients of transmission of the diseases for infective and expose individuals, respectively. The parameter *p* is the fraction of exposed individuals who go to the

infective compartment. Furthermore, $\beta$, $\mu$, $1/\gamma$ and $1/\delta$ denote the transmission rate, death rate, the average incubation period of the disease, and average infectious infection, respectively. The Runge-Kutta method is used for solving the SEIRD model equations. During the solution of equations numerically for each compartment, we have used various choices of parameters (Table 1) and time intervals.

**Table 1**: **Definitions and values of parameters for Covid-19**

| Parameter | Definition | Value | Reference |
|---|---|---|---|
| $\beta$ | Transmission rate | 0.001 | Worldometer[24] |
| $\varepsilon_1$ | Coefficient of transmission for the infective individual | 0.8 | … |
| $\varepsilon_2$ | Coefficient of transmission for the exposed individual | 0.5 | … |
| $p$ | Fraction of exposed | 0.12 | … |
| $\gamma$ | Exposed rate | 1/6 | WHO[25] |
| $\delta$ | Recovery rate | 57.31 | WHO[26] |
| $\mu$ | Death rate | 1.32 | WHO[26] |

**Basic reproduction number:** Let $X(E,I)$ be the group of disease compartments and $Y(S,R_e,D)$ be the group of non-disease compartments. Further, consider $f(X,Y)$ is the rate of secondary infection that increase in the disease compartments and $v(X,Y)$ is the rate of other progression progressions such as death, the recovery that decrease in the disease compartments, respectively. The diseased compartment can be expressed as

$$\frac{\partial X}{\partial t} = f(X,Y) - v(X,Y) \qquad \text{Equation No. 6}$$

where $f = \begin{bmatrix} \beta S(\varepsilon_1 I + \varepsilon_2 E) \\ 0 \end{bmatrix}$ and

$v = \begin{bmatrix} \gamma E \\ -p\gamma E + (\mu+\delta)I \end{bmatrix}$

According to a author[10], the basic reproduction number is defined as the positive eigenvalue of the next generation matrix $k = FV^{-1}$ where $F = \frac{\partial f}{\partial X}(0,Y_0)$ and $V = \frac{\partial v}{\partial X}(0,Y_0)$. That is, we can write the time-dependent reproduction number $R_0$ as

$$R_0 = FV^{-1} \qquad \text{Equation No. 7}$$

where $F = \begin{bmatrix} \varepsilon_1\beta S_0 & \varepsilon_2\beta S_0 \\ 0 & 0 \end{bmatrix}$ and

$V = \begin{bmatrix} \gamma & 0 \\ -p\gamma & \mu+\delta \end{bmatrix}$.

After simplification, the basic reproduction number can be derived as

$$R_0 = \beta S_0\left(\frac{\varepsilon_1}{\gamma} + \frac{p\varepsilon_2}{\mu+\delta}\right) \qquad \text{Equation No. 8}$$

The average basic reproduction number ($R_0$) is defined as proportional to the contact rate and will vary according to the local condition. $R_0$ can be affected by several factors and essentially, $R_0 > 1$, $R_0 = 1$, and $R_0$ less than 1 mean epidemic is happening in a susceptible population, the disease is endemic and the epidemic is declined, respectively. To effectively eliminate an epidemic disease from a population, $R_0$ needs to be less than unity.

**Results**

**Model fitting with data:** Bangladesh has recorded 479740 confirmed cases with 6874 fatalities by December 07, 2020. The first confirmed cases were documented on March 08 and the first death on March 18, 2020. As of December 07, 2020 398623 infected people have been recovered; pushing the recovery rate is 83.09 percent. The data of reported cases recovered and death due to the Covid-19 outbreak is obtained from IEDCR, Worldometers, and Johns Hopkins University.

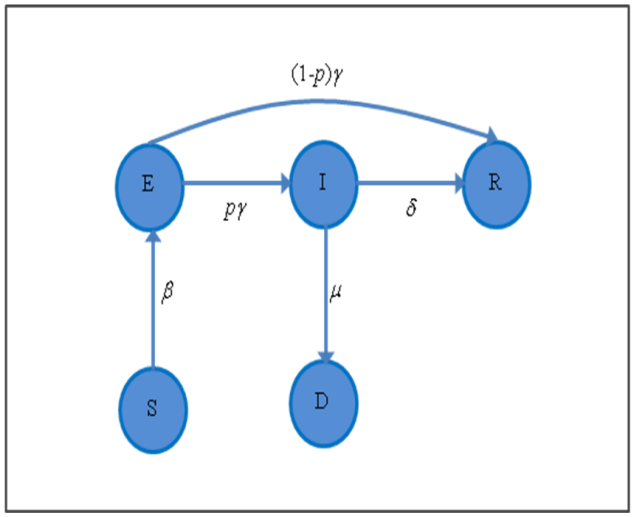


**Figure I:** Diagram of the model described by the Eqs. (1-5).

The reported data is compared with the SEIRD model's results to forecast the possible infective, recovery, and death cases in Bangladesh. According to Figure II, the fitting of a model is highly related to the time-length of reported data taken into reflection. The change in estimated curves owing to varying sizes of data is evident. Nevertheless, taking recent data of 200 and 250 days from its beginning in Bangladesh, the calculated results pink and green solid lines, respectively show a nice fit for the reported cases and death (Figure II). That is, the calculated model results and observed data for 200 and 250 days converge to similar values and are very close to the reported cases, confirming our optimization method of the parameters.

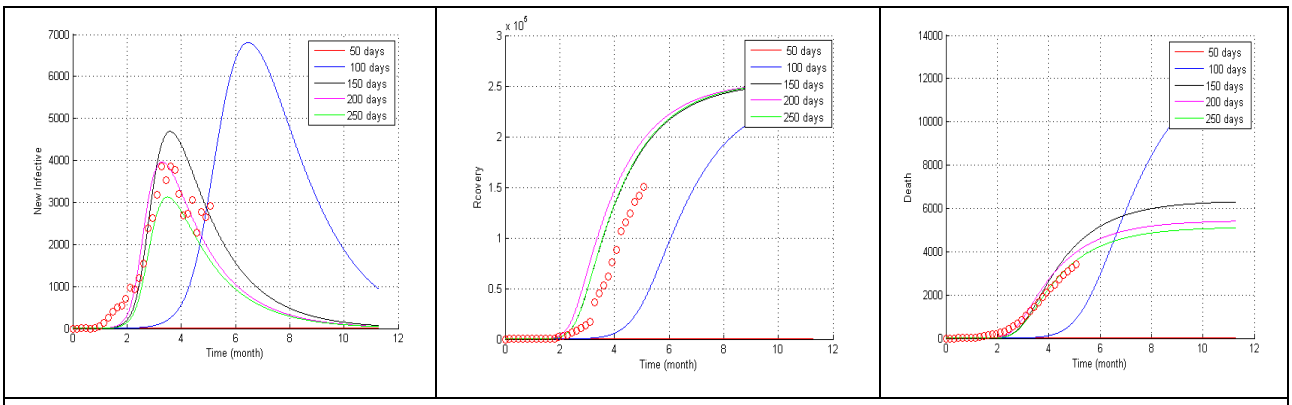


**Figure II:** Comparisons of infected, recovered, and death cases of Covid-19 with reported data as a function of time. Reported active cases are shown in red circles. The first identified date on March 08, 2020

**Reproduction Number:** The model-implied reproduction number ($R_t$) varies remarkably over a period and gives systematic and regular updatable data to calculate the immediate results of these travels (Figure III). We have estimated the daily basis time-varying reproduction number taking the reported median incubation period of 6 days. In the beginning, the estimated values of the reproduction number show lower and less than 1 for all cases. That is, the model-implied $R_t$ for Bangladesh exhibits some downward and upward of zero line lines from starting to May ($t$ = 60 days) and after that, it remains above 1 and decreases from August 23 ($t$ = 163 days) to October ($t$ = 226 days). It is also observed that $R_t$ again increases from the beginning of October ($t$ = 230 days) to December 07 ($t$ = 270 days) which gives the alarming of second waves of coronavirus.

**Statistics of Infections:** We studied the publicly existing materials reported by the IEDCR and WHO to display the potential of Covid-19 to spread without nourishing severe health measures. Figure IV(a) shows the cumulative number of infections due to Covid-19 outbreaks month-wise. According to Figure 4(a), the highest number of infections is observed in the 4$^{th}$ month from the reported date. On the other hand, the total numbers of people infected with Covid-19 are shown in Figure IV(b) for several age groups until December 07, 2020. It is seen that the infected rate is higher among the people of the 31-40 age groups at 26.7%. The second highest infection rate is registered as 19.7% among the 21-30 age groups of people. As of December 07, 2020, among the total number of reported cases, 72% of infected persons were recorded as male and the rest 28% as female [Figure IV(b)].

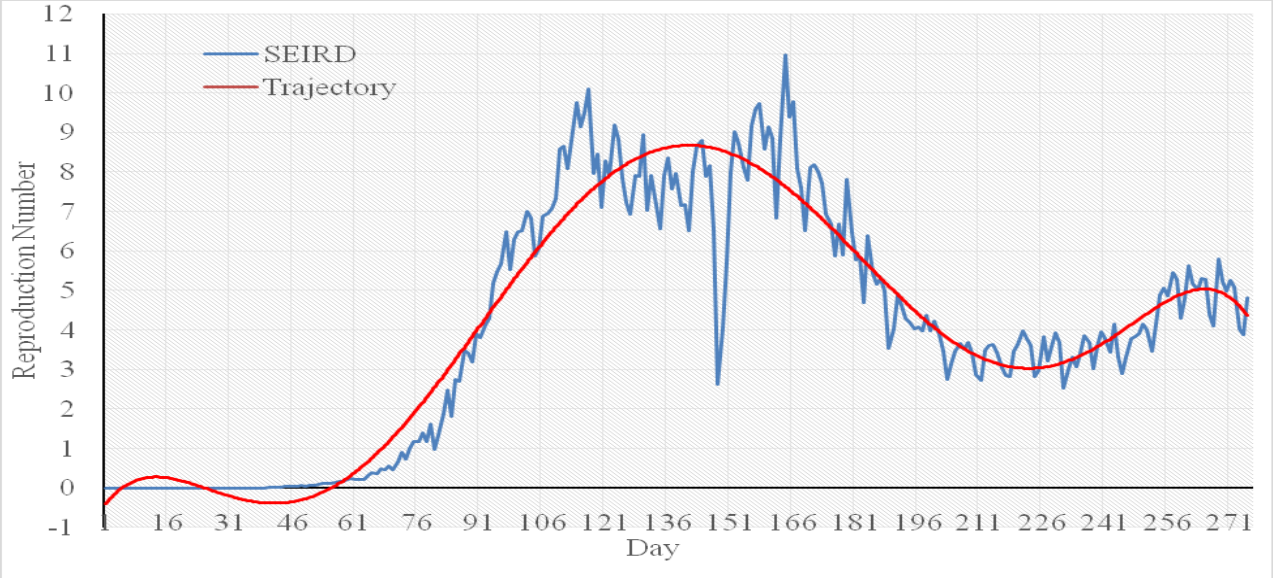


**Figure III: Graph of time-dependent reproduction number**

**Statistics of Deaths:** There are 6,874 deaths due to Covid-19 in Bangladesh to date December 07, 2020. Figure V shows the cumulative number of deaths due to Covid-19 outbreaks month-wise and age-wise. Figure V(a) is showing the monthly distribution of deaths from March 08 to December 07, 2020. According to Figure V(a), although the highest numbers of deaths are observed in the 4$^{th}$ month from the reported date and this trend is continued up to the 6$^{th}$ month. Although from the 7$^{th}$ month, the number of deaths started to decrease but in the 9$^{th}$ month, it again increases. Furthermore, the death rates are presented for different age groups in Figure 5(b) and it is seen that with increasing age the percentage of death is also increased. The highest death rate (53.5%) is reported in the age group of 61 and above years old. The next highest death rate (25.9%) is observed in the age group of 51-60, where children and younger age groups (< 10, 11-20, 21-30) have relatively fewer percent of deaths. Besides, the gender distributions of the total death rate of males and females are observed around 76.5% and 23.5%, respectively in Figure V(b). The death rate is 3.25 times higher in males than females and females are also relatively less infected than males (IEDCR).

**Figure III: Graph of the Time-Dependent Reproduction Number**

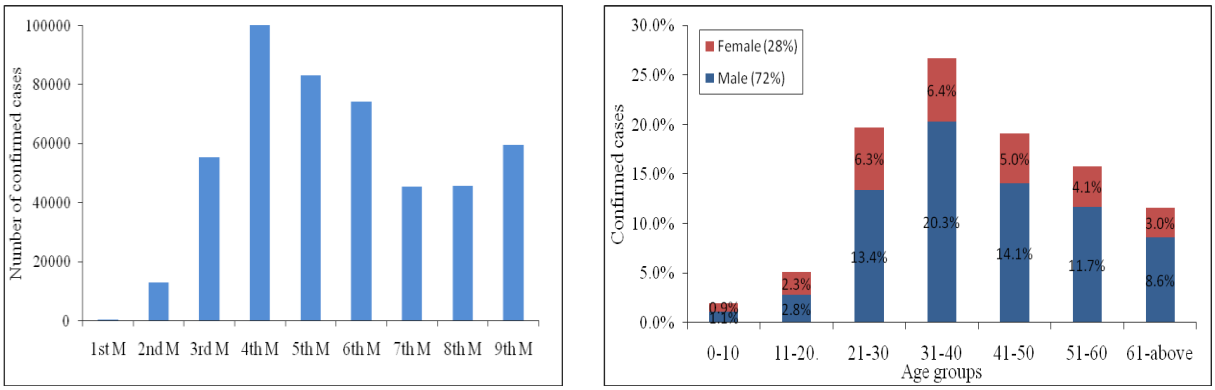


**Figure IV:** Graphs of Left infection distributions in month-wise (M=month) and Graphs of Right infection rates in various age groups and gender. Data are taken from March 08 to December 07, 2020.

**Statistical Approach:** In this direction, statistical data of people who have been affected and died by the disease of Covid-19 has been shown from March 08, 2020, to December 07, 2020, in Figure VI. Figure VI(a) presents the data of confirmed cases against the time variations. It is seen that data are well correlated by the following empirical relationship:

$$Case(Day) = 0.00002(Day)^4 - 0.008(Day)^3 + 1.090(Day)^2 - 18.15(Day) - 116.2 \quad \text{Equation No. 9}$$

which was derived using 275 data and the *R*-squared value was found as $R^2 = 0.816$.

Again, Figure 6(b) shows the results for all data of death in the above mentioning period. The results demonstrate a significant correlation between *Death* and *Day*, which yields:

It is seen in Figure 6 that the data residing much closer with the polynomial function (Eq. 9 and Eq.10) which can be concluded that it could be helped to determine the peak period and size. After analyzing a similar type of data by extrapolation, [6] proposed that the exponential distribution function was the most suitable model for predicting the peak time.

$$Death(Day) = 0.0000002(Day)^4 - 0.000(Day)^3 + 0.017(Day)^2 - 0.482(Day) + 2.816 \quad \text{Equation No. 10}$$

where $R^2 = 0.793$ is the determination coefficient of the regression law.

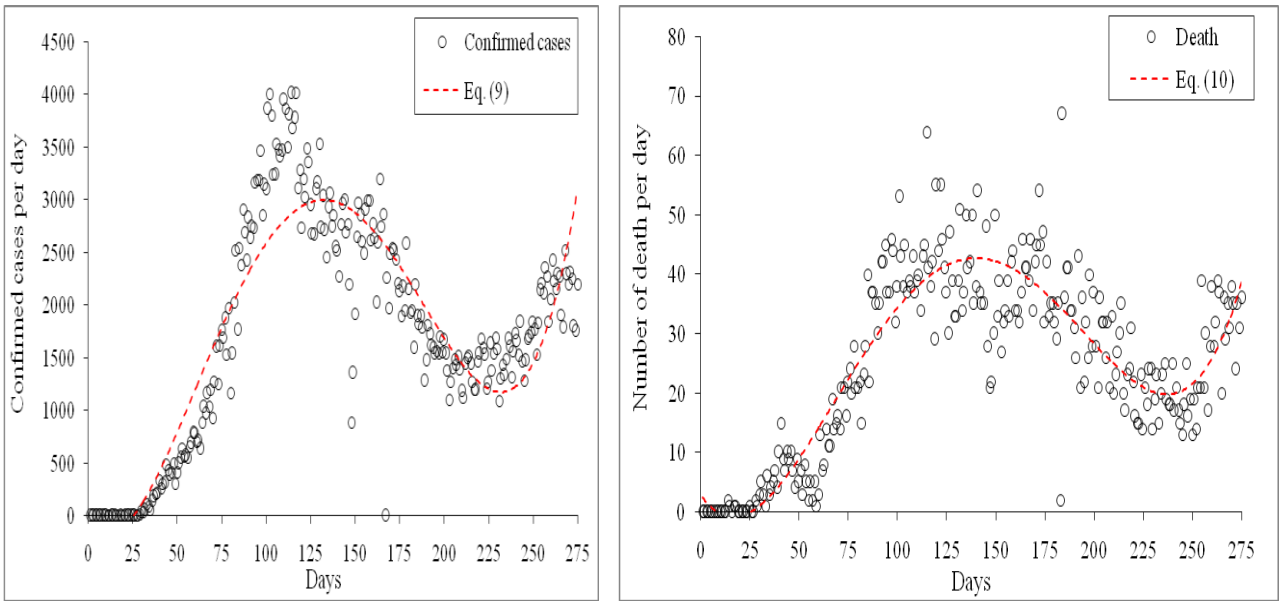


**Figure V:** Displays of (a) death distributions due to Covid-19 in month-wise (M=month) and (b) death rates in different age groups and gender. Data are taken from March 08 to December 07, 2020

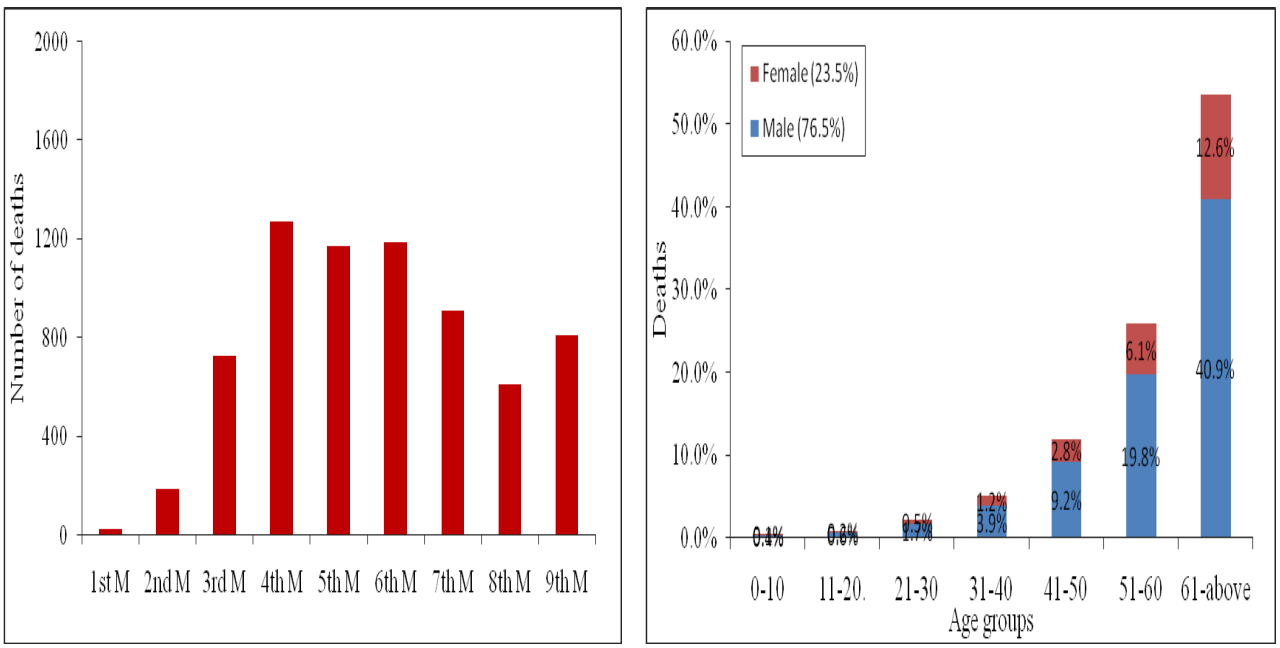


**Figure VI:** Different extrapolation functions: (a) daily infections and (b) daily deaths.

**Mutation, tests, treatment, and public awareness:** According to the Bangladesh Council of Scientific and Industrial Research (BCSIR), the Covid-19 mutation rate in Bangladesh was 12.6 percent which was faster than the global average rate of 7.23 percent. They found this figure based on the data of 263 cases of genome sequencing from eight divisions of the country. The samples were collected from 7 May to 31 July 2020. The dominant variant G614 was found in 100 percent of the collected samples. Recently, explored the mutation rate of the entire genomic sequence collected from the patient's data set of several countries and they determined the nucleotide and codon mutation separately[20]. To understand viral evolution, the mutation rate is one of the crucial parameters. Since mutation generates new subtypes of the virus; it needs the progress of an active vaccine or medicine for it. But knowing the clinical types of the virus severe or minor is also very important, because it may help to develop a strategy to suppress the transmission.

Bangladesh had an insufficient number of testing kits initially: it might have less than 100 thousand testing kits in stock, among them only near about 20 thousand kits had been distributed with the different testing facilities everywhere in the country. Five weeks after the identification of the Covid-19 in Bangladesh, the IEDCR had only tested 11223 people, constituting nearly 68 tests per million populations. The number of Covid-19 testing laboratories has only risen over time and approximately, 4410 tests per million people have been carried out till June 29, 2020, that is still not enough. Although the number of laboratories for Covid-19 testing has increased to 140 and the number of daily tests reached the highest of approximately 18426 thousand on June 30 and the total numbers of tests were performed 2877538 on December 07, 2020[24].

Bangladesh has planned to give the doses to 20 to 25 people on the first day (January 27, 2021). Although plasma with antibodies from recovered Covid-19 patients was given to some affected people in Bangladesh, but the response was found not so good. The improved outcomes in recipients of convalescent plasma obtained in two recent small studies in China[21-22] support the possibility of investigating this therapy further inadequately designed clinical trials. Besides supportive care and oxygen supplementation, WHO also recommended some preventive measures which include washing hands, avoiding touching the eyes, keeping unwashed hands from mouth or nose, practicing good respiratory sanitation, staying at home, leaving the crowded place, maintaining social distance, covering one's mouth when coughing and sneezing, self-isolated himself if someone suspected himself that he might be affected.

In response to Covid-19, the government of Bangladesh, as well as IEDCR has raised a national-level alert and applied public health actions under WHO guidelines to combat the virus. They, however, believe that the spreading of Covid-19 may depend on human intervention and safeguard, such as strict enforcement of worldwide masking, physical distancing, improving hand sanitation, and increasing testing and isolation. However, not have of public awareness and widespread fear and nervousness related to an unknown disease among the general people, as well as limited health facilities, pose unique challenges and a massive threat to the population[23]. The Covid-19 seems to be transmitted from an infected person to a person through respiratory droplets and close contact.

## Discussion

The time-dependent cumulative infection rate was set for 250 days in the model; the predicted curve (green solid line) showed a nice fit for the reported cases. We obtain that peak active infected cases could reach around 4000 by end of June 2020 in Bangladesh. On the other hand, although the calculated curve for death is well consistent with the 250 days data, the recovery curve is not. The reason for this may be the recovery data were not well recorded (Figure II).

In Figure III, we estimated the time-dependent reproduction number $R_t$ for each day. We have estimated the average basic reproduction number ($R_0$) over 15 days and the value of this parameter is found to be 3.79 (95% CI: 2.46–5.12), which is also depending on the estimates of the SI during the early epidemics. The estimated basic reproduction number $R_0$ is significantly larger than 1 and this number can be varied owing to patterns of individual's contacts differing from country to country for cultural and educational reasons[11]. Also, $R_0$ can be different in subpopulations[12].

The mitigation and conquest plans have been accomplished to control the spread of the infection and decrease the reproduction number through reduction of contact and lower the possibility of transmission. Maintaining the above strategies is expected to control the epidemic size and keep the value of $R_0$ below 1.

The statistics of Covid-19 in Bangladesh showed that the highest numbers of infections and deaths were observed in the 4th month from the reported data [Figure IV(a) and V(a)] that were consistent with the America, Brazil, Russia, India outbreaks[13]. The Covid-19 pandemic was controlled within the first 3 months from the identified date data for all the countries, but it became out of control in the 4th month from the reported date[13]. Also, the infected and death rate were observed highest among the age group of 31-40 and 61-above, respectively. Again, the infected rate and death rate were observed 2.57 and 3.26 times higher in males than females, respectively. Similar estimations were measured for Covid-19 in Bangladesh[16]. Still, now researchers give emphasis to know why females are less affected than males, smoking primarily seems to be the main culprit. But after data accumulated, virus specialists realized that smoking is not only the reason, the male may have been more likely to be exposed to the virus for social or cultural reasons[14].

Recent studies[14-15] suggested that there were significant differences in the immune system between males and females due to sex hormones, so females reduced vulnerability to viral infections could be due to the defense of X chromosomes and sex hormones which might be played a vital role in immunity. Older age groups are more likely to have co-morbidities like diabetes, hypertension, chronic respiratory disease which increase the chance of developing severe symptoms. Similar observations were done[16]. Pathologically several studies show that lung epithelial cells that express Angiotensin-converting enzyme-2 (ACE-2) are the primary receptor for the entry of the Covid-19 virus[17-19]. This ACE-2 receptor is dramatically reduced with increasing age for both genders. The study also shows that down regulation is significantly higher in males than females[17], which can result in an increased risk of severity and fatal condition in males than females.

## Conclusion

Characteristics of the coronavirus became either more weakened or more strengthened when it was mutated. Based on the mutation rate and different symptoms of Covid-19, the local experts warned that the deadly coronavirus might hit Bangladesh even harder in the coming winter. Some control suggestions were recommended along with the state, citizens must preserve social isolation, their personal awareness, their basic hygiene, their self-quarantine condition and respect national and WHO laws.

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