

# Estimation and Prediction of Case Fatality Rates, Recovery-to-Death Ratio of COVID-19 Disease during the Second Wave in Bangladesh

## Estimativa e previsão de taxas de letalidade, taxa de recuperação / óbito da doença COVID-19 durante a segunda onda em Bangladesh

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### Abstract

**Objectives:** This study aimed to estimate the CFR and RDR of COVID-19 disease during the second wave in Bangladesh and also intended to predict the trend of COVID-19 infected and death cases, case fatality rate (CFR) and recovery-to-death ratio (RDR) using Facebook Prophet Model (FPM). **Methods:** Daily time series data of COVID-19 cases for 512 days used in this study was taken from worldometer. The FPM was used to predict the daily infections, deaths, CFR, and RDR of COVID-19 disease in Bangladesh as of August 01, 2021. **Results:** About 71% male and 29% female people were infected, most susceptible age group to be infected was 21 to 30 (27.6%) and below 10 (2.9%) was the least infected group as of August 01, 2021. The oldest age group (>60) was the most endanger to death (55.2%) and the youngest (<10) was the least death (0.3%) age group. Overall CFR was found at 1.654% which is less than the world CFR (2.13%) on August 01, 2021. The RDR was estimated at 52.269 which is below the world RDR 42.36 on August 01, 2021, in Bangladesh. Predicted infections and deaths exhibited an upward trend, daily CFR designates roughly constant trend, and daily RDR indicates a downward trend in Bangladesh at this ongoing second wave. **Conclusion:** The male people are more prone to be infected and dead. The oldest age group is more threatened to death and the youngest is least due to COVID-19 in Bangladesh. Both the predicted infections and deaths increasing, daily CFRs are roughly constant and daily RDR is decreasing in the second wave in Bangladesh due to the COVID-19 pandemic.

**Keywords:** Novel Coronavírus; Facebook Prophet Model; Pandemic. Vaccine; Bangladesh.

### Resumo

**Objetivos:** Este estudo teve como objetivo estimar o CFR e RDR da doença COVID-19 durante a segunda onda em Bangladesh e também prever a tendência de casos de infecção e morte por COVID-19, taxa de letalidade (CFR) e taxa de mortalidade de recuperação (RDR) usando o Facebook Prophet Model (FPM). **Métodos:** Dados de séries temporais diárias dos casos COVID-19 para 512 dias usados neste estudo foram retirados do worldometer. O FPM foi usado para prever as infecções diárias, mortes, CFR e RDR da doença COVID-19 em Bangladesh a partir de 01 de agosto de 2021. **Resultados:** Cerca de 71% dos homens e 29% das mulheres estavam infectados. A faixa etária mais suscetível a ser infectada era de 21 a 30 (27,6%) e abaixo de 10 (2,9%) era o grupo menos infectado em 01 de agosto de 2021. O mais velho A faixa etária (> 60) era a que apresentava maior risco de morte (55,2%) e a mais jovem (<10) era a com menor risco de morte (0,3%). O CFR geral foi encontrado em 1,654%, que é menor do que o CFR mundial (2,13%) em 01 de agosto de 2021. O RDR foi estimado em 52,269, que está abaixo do RDR mundial de 42,36 em 01 de agosto de 2021, em Bangladesh. As infecções e mortes previstas exibiram uma tendência ascendente, o CFR diário indica uma tendência quase constante e o RDR diário indica uma tendência descendente em Bangladesh nesta segunda onda em curso. **Conclusão:** Os homens são mais propensos a serem infectados e mortos. A faixa etária mais velha está mais ameaçada de morte e a mais jovem é a menos devido ao COVID-19 em Bangladesh. Tanto as infecções previstas quanto as mortes aumentam, os CFRs diários são quase constantes e o RDR diário está diminuindo na segunda onda em Bangladesh devido à pandemia de COVID-19.

**Palavras-chave:** Novo Coronavírus.; Modelo de Profeta do Facebook; Pandemia; Vacina. Bangladesh.

### INTRODUCTION

The coronavirus disease 2019 (COVID-19) caused by the novel Coronavirus strain SARS-CoV-2 rapidly developed into a worldwide pandemic<sup>1,2</sup>. The outbreak of novel coronavirus was first reported in Wuhan, Hubei province, China in December 2019 and has affected almost all countries and territories in the world<sup>3,4</sup>. It is a highly infectious disease touching every corner of the world, affects every country without considering the country's nationality, race, and economic status<sup>5</sup>. Because of its high infection rate, COVID-19 has already caused widespread

mortality and morbidity in most of the countries throughout the world and it has now become one of the main global public health challenges<sup>6</sup>. The World Health Organization (WHO) first declared COVID-19 as the Public Health Emergency of International Concern<sup>4</sup> and then the outbreak of novel Coronavirus was declared as a global pandemic by WHO<sup>7</sup>. The ongoing pandemic not only created public health crisis but also created development and humanitarian crisis and moving like a wave causing deaths and weakening economies globally<sup>8</sup>.

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## 2 Estimation and Prediction of COVID-19 during the Second Wave in Bangladesh

As of August 01, 2021, 19,78,65,160 COVID-19 confirmed cases and 42,19,861 COVID-19 attributable deaths were documented worldwide due to COVID-19 by 01 August 2021<sup>9</sup>. People of all ages across the world have been affected both physically and psychologically by the current COVID-19 pandemic<sup>10</sup> and the psychological effect of this pandemic may persist for several months or years<sup>11</sup>. The COVID-19 disease and its devastating outcomes have led people to panic, fear, stigma, anxiety, depression, and xenophobia around the world<sup>12</sup>. The ongoing pandemic has also triggered the negative universal psychological impact which has been termed as “coronaphobia”<sup>13</sup>.

Bangladesh is one of the high-risk countries in the world to be affected by the fast-spreading novel coronavirus and various vulnerabilities intensify the adverse impacts of COVID-19 and create multidimensional crisis<sup>14</sup>. In Bangladesh, the first infected cases of COVID-19 were reported on 08 March 2020 and the first confirmed death of coronavirus-affected patients was reported on 18 March 2020 by the Institute of Epidemiology, Disease Control and Research (IEDCR), Bangladesh<sup>15</sup>. The disease has spread out across the country within a very short period of time. Mueyed et al. (2021) presented that the daily highest Case Fatality Rate (CFR) country was Bangladesh among the SAARC affiliated countries followed by Afghanistan, India, Sri Lanka, Pakistan, Nepal, and the Maldives according to the maximum CFR of the countries until 24 October 2020<sup>16</sup>. To stop the COVID-19 pandemic, the Government of Bangladesh took several necessary steps such as countrywide lockdown, local or international flight bans quarantine of suspected cases, enforcement of social distancing, isolation of infected patients, mask-wearing, and personal hygiene maintenance and so on<sup>14,17</sup>. All these steps can mildly slow down the pandemic<sup>17</sup>. Moreover, it is extremely difficult to lock down millions of people considering the population density, social structure, environmental factors, cultural norms, and poverty in Bangladesh<sup>12</sup>. Vaccination is one of the most effective tools which can prevent and control the COVID-19 pandemic<sup>18</sup>. Many countries in the world adopted mass COVID-19 vaccination programs, Bangladesh is not far behind. The Bangladesh government launched the administration of COVID-19 vaccines on 27 January 2021<sup>19</sup> and the countrywide mass vaccination program started on 7 February 2021 by using Oxford-AstraZeneca Covid-19 vaccine (Covishield)<sup>20</sup>. At present in Bangladesh, several COVID-19 vaccines such as Pfizer-BioNtech (Comirnaty), Moderna (Spikevax), Sinopharm (Vero Cell), Oxford-AstraZeneca (Covishield) from various sources are being given to everyone within a certain age limit under the mass COVID-19 vaccination programs.

Bangladesh has been observing the rising number of daily recorded cases and deaths dominated by the beta variant (B.1.351) of coronavirus, since the third week of March 2021<sup>21</sup>. It became the most prevalent variant at that time causing a huge public health concern resulting in the second wave of COVID-19 in Bangladesh<sup>22</sup>. The double mutated delta variant of COVID-19 (B.1.617.2) was first identified in India in October 2020 and has now been detected across the globe<sup>23</sup>. It appears to be more infectious and causes more severe infections than

other variants<sup>24</sup>. The pandemic situation in India has taken a drastic turn after identifying the delta variant of COVID-19 by record-breaking new cases and deaths<sup>25</sup>. The delta variant of COVID-19 is thought to be 60% more infectious than the more common alpha variant<sup>26</sup>. The first cases of COVID-19 infection by delta variant (B.1.617.2) were first reported on May 8, 2021, in Bangladesh<sup>25</sup>. This Delta variant might have been imported into Bangladesh through the movement of population in the border area of India and Bangladesh<sup>21</sup>. Then this newly identified delta variant of COVID-19 has spread quickly since first being reported emerged as the dominant cause of COVID-19 disease and death. The situation is worsening because the number of infected people and the number of deaths due to COVID-19 increased day by day. We are observing a new record almost every day in terms of the number of infected and the number of deaths due to COVID-19 in Bangladesh. A total number of 12,64,328 confirmed cases have been recorded in Bangladesh, 10,93,266 of which have recovered, and 20,916 deaths have been reported till August 01, 2021<sup>27</sup>. The delta variant in Bangladesh is a concern for the country because medical facilities, such as hospital beds, intensive care units (ICU), oxygen supply for critical patients, ventilators, are far fewer than the required amount in both government and private hospital<sup>23,28</sup>. Health experts think that the infection and death pattern of the second wave of the COVID-19 pandemic would be more severe than the first wave<sup>29</sup> and World Health Organization has warned about the third wave of COVID-19<sup>30</sup>. The case fatality rate (CFR), which is an important parameter to measure the severity of infections of a disease like COVID-19, was relatively higher among the old age population, medical professionals, and law enforcement staff during the first wave of COVID-19 in Bangladesh. But in the second wave, infections are occurring among all age-sex groups and all peoples engaged in different professions and CFR is also high among all these groups of the population. The Case Fatality Rate (CFR), Recovery to Death Ratio (RDR), and trends of infection and death pattern are the most important key issues to understand the basic epidemiological features of the outbreak of the COVID-19 which will help the policymaker and public health experts to tackle the ongoing pandemic. Thus, in this study, we aimed to estimate CFR and RDR of COVID-19 disease during the second wave in Bangladesh till 01 August 2021. We also intended to explore the trend of COVID-19 infected cases, death cases, CFR, and RDR using the Facebook Prophet Model (FPM).

## METHODS

### Data Source

The data of daily infections, daily recovery, and daily deaths for this study has been extracted from the Worldometer observing daily data. The extracted data were also cross-checked with the daily COVID-19 Bangladesh situation reports published by the World Health Organization (WHO). The first COVID-19 infected patient was diagnosed on 8 March 2020 in Bangladesh and that is why the daily data was extracted from this day. We took daily data for 512 days from March 08, 2020, to August 01, 2021, for

this study.

One person is recognized as an infected case of COVID-19 who tested positive by reverse transcription-polymerase chain reaction (RT-PCR) test respiratory specimen of nucleic acid, GeneXpert, and Rapid antigen tests. One person is recognized as a recovered case who tested positive first and showed negative results in two consecutive tests. One person is declared as a death case who first identified as a COVID-19 positive patient before dying. A total of 12,64,328 infected cases has been recorded in Bangladesh, of which 10,93,266 recovered, and 20,916 deaths have been reported as of August 01, 2021<sup>27</sup>.

### Statistical Methods

The Facebook Prophet Model (FPM) is a device for forecasting or predicting events or cases over time<sup>31</sup>. The model is in additive type and combined with three components as

$$y(t)=g(t)+s(t)+h(t)+\epsilon_t$$

Here,  $g(t)$  is the trend function of the time series,  $s(t)$  represents periodic changes,  $h(t)$  represents holiday component and  $\epsilon_t$  represents the error term which is normally distributed. One of the most common tools to measure the risk of dying in a pandemic is the case fatality rate (CFR). The CFR is defined by dividing the number of deaths from a specified disease over a defined period of time by the number of individuals infected with the disease during that time and the resulting ratio is then expressed as a percentage multiplying by 100<sup>32</sup>. The decreasing trend of daily CFR can be interpreted as the percent of dying is decreasing over time compare to infected cases due to a specific disease. The ratio of the cumulative number of infected cases recovered or cured of a disease over the cumulative number of deaths over time by that disease is termed as a recovery-to-death ratio (RDR). This measure represents the percentage of patients recovering compared to dying from a specific disease. If the trend of RDR reveals an increasing pattern then it is interpreted as the recovery rate is comparatively higher compare to deaths by any disease. The CFR and RDR are sensitive to the number of testing and infected cases. The statistical analyses used in this study were done using the R 4.0.5 version of statistical software.

### RESULTS

As of August 01, 2021, total tests conducted by RT-PCR lab (92.8%), Rapid antigen (6.3%) and GeneXpert lab (0.9%) were 77,90,423 and total infected cases found 12,64,328 in Bangladesh. Infection rate over tests is found 16.22%, recovery and death rates are 86.5% and 1.654% respectively till first August 2021. Hence, the active cases rate of COVID-19 who are under treatment either in a hospital or home is 11.9%. According to the current population of Bangladesh, the number of tests, infections, and deaths per million people are 46801, 7595 and 126 respectively as of August 01, 2021. Bangladesh ranked 26, 29, and 50 according to total infections, deaths, and

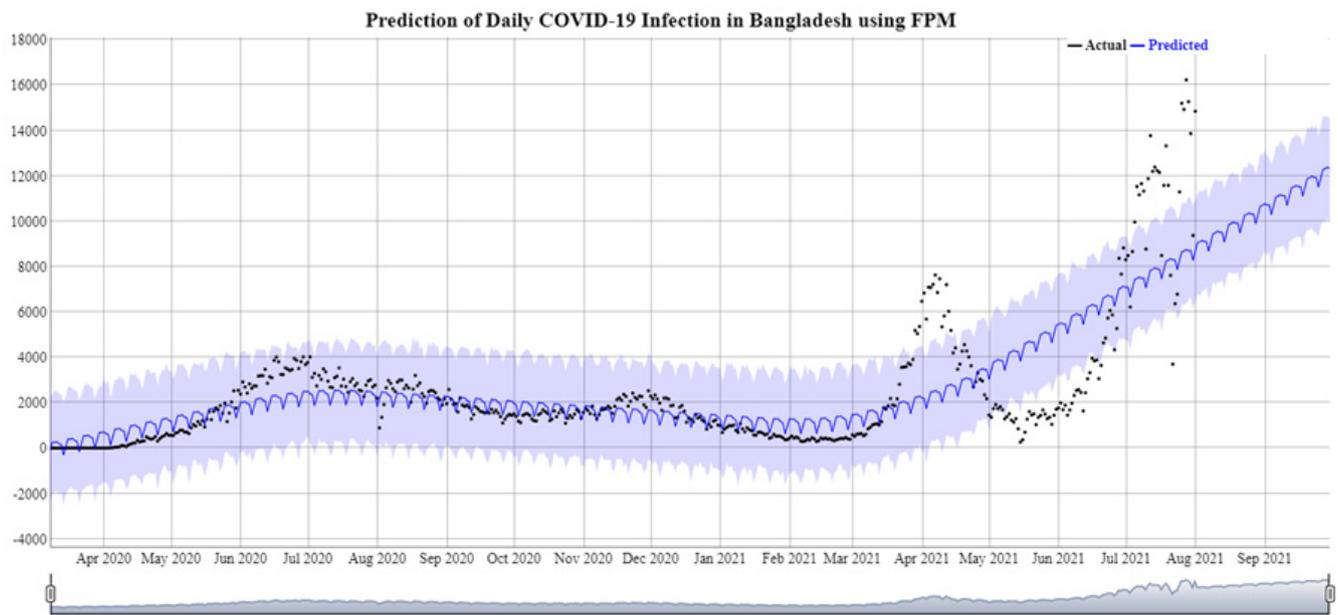
tests in the world as of August 01, 2021. Maximum infections were reported in a single day so far 16230 that was on July 28, 2021, and maximum deaths were in a single day 258 that was reported on July 27, 2021, until August 01, 2021. More than half of the infected patients (60.1%) were reported from the Dhaka division followed by Chattogram (14.4%), Khulna (7.4%), Rajshahi (6.6%), Rangpur (3.5%), Sylhet (3.2%), Barishal (2.7%) and 2.1% from Mymensingh division. The majority of the deaths reported by SARS-CoV-2 was from the Dhaka division (45.7%) followed by Chattogram (18.7%), Khulna (13.3%), Rajshahi (7.7%), Rangpur (5%), Sylhet (3.7%), Barishal (3.2%) and Mymensingh (2.7%) as of 01 August 2021. The correlation coefficient between the daily number of tests conducted in the last 24 hours and daily reported infections is estimated at 0.88.

About 71% male and 29% female people were infected by a novel coronavirus in Bangladesh as of August 01, 2021. Most susceptible age group to be infected was 21 to 30 (27.6%) followed by 31 to 40 (27.1%), 41 to 50 (17.3%), 51 to 60 (11.2%), 11 to 20 (7.3%), above 60 (6.7%) and below 10 (2.9%) as of August 01, 2021. More than half of the dead people were male (67.6%) and only 32.4% were female by a novel coronavirus. Oldest age group (>60) (55.2%) was most threatened to death followed by 51 to 60 (23.7%), 41 to 50 (12.1%), 31 to 40 (5.9%), 21 to 30 (2.2%), 11 to 20 (0.6%) and youngest (<10) (0.3%) in Bangladesh as of August 01, 2021.

Overall estimated CFR of Bangladesh by COVID-19 was found 1.654% which is less than the world CFR (2.13%). The estimated CFR for males (1.58%) is less than the CFR of females (1.85%) on August 01, 2021. The highest CFR is found among older age group (>60) (13.62%) followed by 51 to 60 (3.5%), 41 to 50 (1.16%), 31 to 40 (0.36%), below 10 (0.16%), 11 to 20 (0.15%) and lowest in 21 to 30 (0.13%) age group. Highest CFR was found by COVID-19 in Khulna division (3%) followed by Rangpur (2.3%), Chattogram (2.2%), Mymensingh (2.1%), Barishal (2%), Rajshahi, and Sylhet (1.9%), and the lowest was found in Dhaka (1.3%) division as of 01 August 2021. The RDR was estimated at 52.269 which is less than the world RDR 42.36 as of August 01, 2021, for Bangladesh.

We are predicting the daily infections, deaths, CFR, and RDR for 60 days from August 02, 2021, to September 30, 2021. This 60 days' time selection for prediction is valid as the second wave is going on in Bangladesh. Figure 1 reveals the trend and prediction of COVID-19 infected cases in Bangladesh. Actual infected cases dropped down in May and June of 2021 but had a sudden increase in July 2021. Predicted infections indicate an upward trend in Bangladesh at this ongoing second wave (Figure 1). Figure 2 discloses the trend and prediction of COVID-19 death cases in Bangladesh. Actual death cases suddenly increase in July 2021. Predicted deaths indicate an upward trend in Bangladesh at this ongoing second wave which is alarming (Figure 2).

**Figure 1.** Prediction of daily infections in Bangladesh using FPM



**Figure 2.** Prediction of daily deaths in Bangladesh using FPM

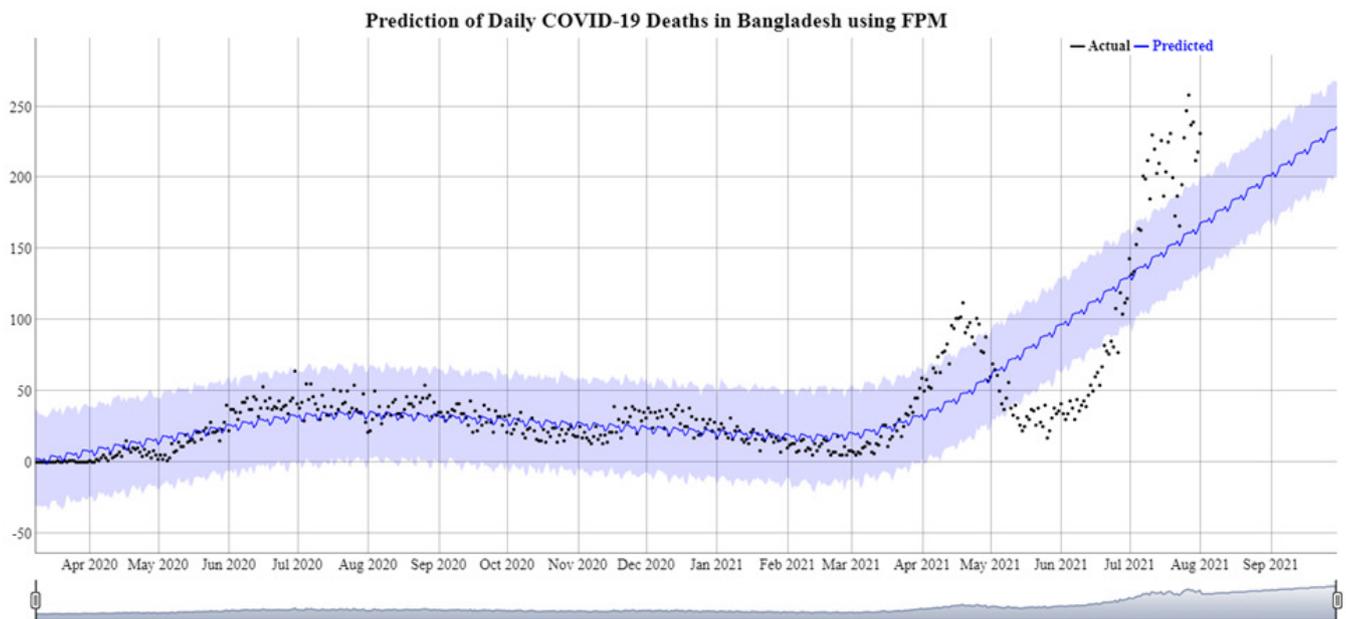
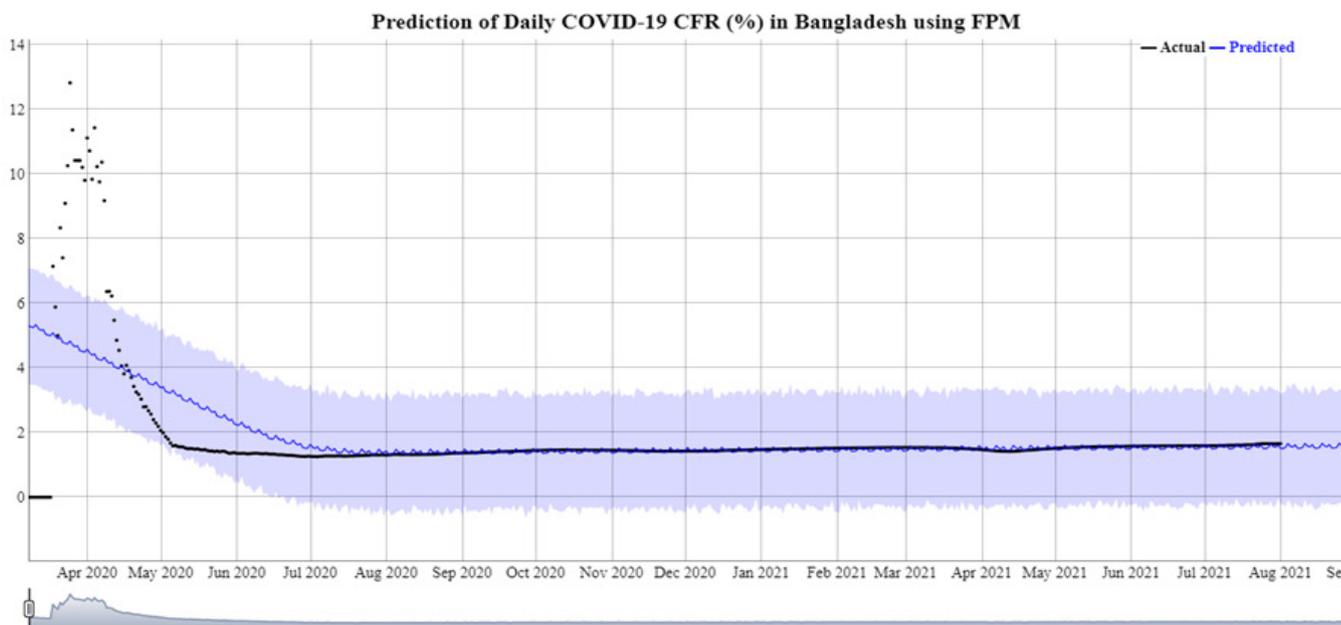


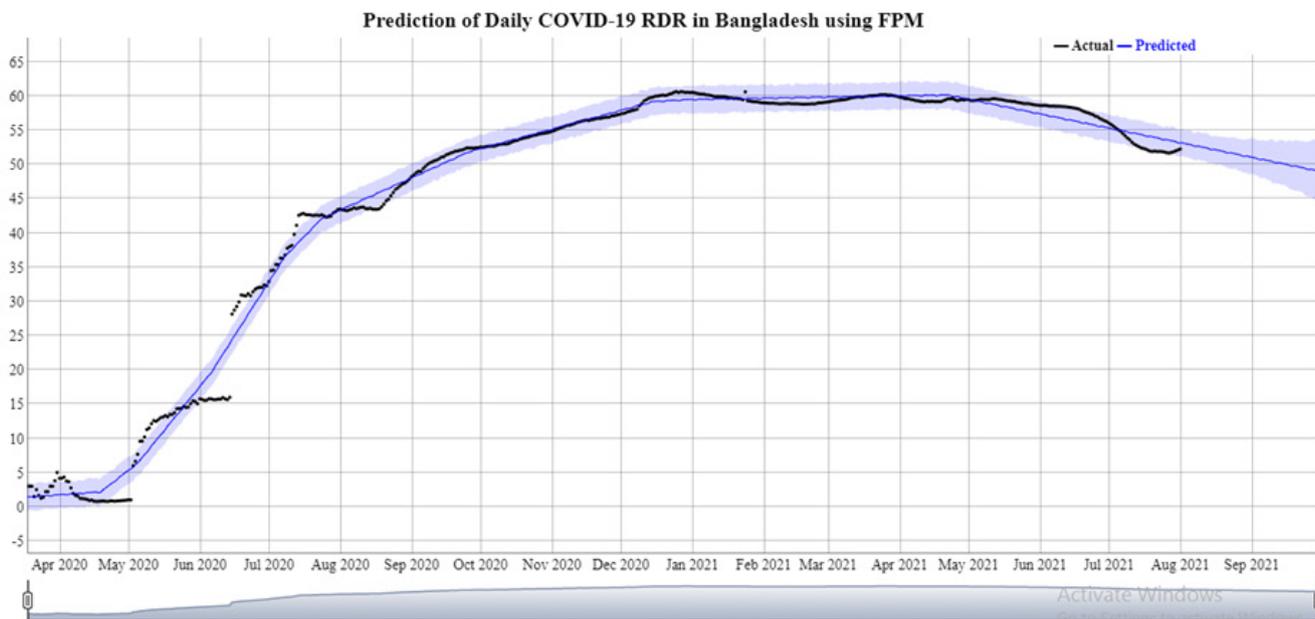
Figure 3 exposes the trend and prediction of daily CFR of COVID-19 disease in Bangladesh. Actual daily CFR fluctuated at the beginning of the COVID-19 outbreak in Bangladesh and then it was almost constant and slightly increased in July 2021. Predicted daily CFR designates a constant trend in Bangladesh till this ongoing second wave (Figure 3). Figure 4 discloses the trend and prediction of daily RDR of COVID-19 cases in Bangladesh.

Actual daily RDR increased from the beginning of the outbreak of COVID-19 disease in Bangladesh but started decreased from the middle of Jun 2021. Also predicted daily RDR indicates an upward trend from the beginning of the outbreak but started dwindling from May 2021 in Bangladesh at this ongoing second wave which is alarming (Figure 4).

**Figure 3.** Prediction of daily CFR (%) in Bangladesh using FPM



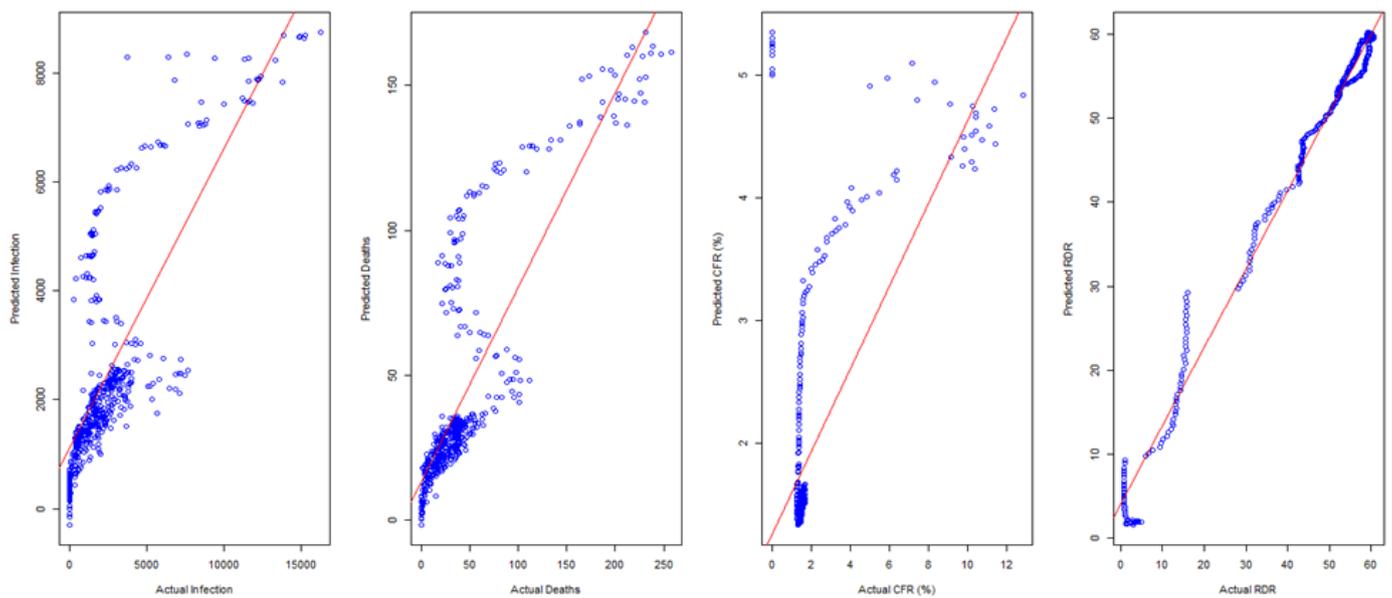
**Figure 4.** Prediction of daily RDR in Bangladesh using FPM



After analyzing the model, actual and predicted data of daily infections, deaths, CFR, and RDR were plotted using a linear model in the plot. From the plot of actual versus predicted values of daily infections, deaths, CFR, and RDR, both underestimation and overestimation were observed heavily in daily infections, deaths, and CFR, and slightly in daily RDR (Figure 5).

The regression model of predicted infections on actual infections provides a very low p-value ( $p < 0.01$ ) with  $R^2$  value of 61%. The

p-value ( $p < 0.01$ ) is found significant from the regression model of predicted deaths on actual deaths with  $R^2$  value of 59%. The result of the regression model of predicted CFR on actual CFR provides a very low p-value ( $p < 0.01$ ) with  $R^2$  value of 40%. The p-value ( $p < 0.01$ ) regression model of predicted RDR on actual RDR is found significantly high with  $R^2$  value of 98.76%. Hence, all the fitted regression models of predicted values on actual values are found significant

**Figure 5.** Scatter plot of predicted and actual cases with a linear line

## DISCUSSION

Male people are more prone to be infected and died by a novel coronavirus in Bangladesh till the ongoing second wave. Muyeed A and Siddiqi MN (2020) reported male sex was more prone to be infected and died compared to females in the first wave in 2020 in Bangladesh<sup>33</sup>. A strong positive correlation is found between the number of daily tests conducted in the last 24 hours and the number of reported infections by analyzing all available data till August 01, 2021. Since there exists a strong positive correlation between the number of tests and reported infections, so more the tests will be conducted more the infected patients will be reported. Hence, Bangladesh needs to increase the daily number of tests. Death rate by novel coronavirus is found associated with age groups. With the increase of age or age groups, death rates also increased in Bangladesh as of August 01, 2021. The oldest age group is most threatened to death and the youngest is the least threatened. Administrative division wise infections and deaths by SARS-CoV-2 have an association. The majority of the infections and deaths were found from the Dhaka division followed by Chattogram, Khulna, Rajshahi, Rangpur, Sylhet, Barishal, and Mymensingh divisions. Muyeed et al. (2020) showed that most of the deaths were from the Dhaka division followed by Chattogram, Khulna, Rajshahi, Sylhet, Rangpur, Barishal, and Mymensingh division in the first wave in 2020<sup>14</sup>.

The overall CFR of Bangladesh by COVID-19 disease is below the world CFR. The CFR of females is larger than the CFR of males that indicates the rate of infected females is more prone to deaths compared to the rate of infected males. Death rate by novel coronavirus is found associated with age groups. With the increase of age or age groups, death rates also increased in Bangladesh as of August 01, 2021. The oldest age group is most threatened to death and the youngest is the least threatened. Maximum CFR was found by COVID-19 in Khulna division

followed by Rangpur, Chattogram, Mymensingh, Barishal, Rajshahi, and Sylhet, and lowest was in Dhaka as of 01 August 2021. The RDR was estimated at 52.269 on August 01, 2021, in Bangladesh which indicates about 52 infected people are being cured when one infected person is being dead.

Predictions were made for 60 days from August 02, 2021 to September 30, 2021 of daily infections, deaths, CFR and RDR of COVID-19 in Bangladesh. Actual infected and deaths cases had a sudden upward trend in July 2021. An upward trend is found in both predicted infection and death cases at this ongoing second wave of a novel coronavirus in Bangladesh. Mahmud, S. (2020) also showed an upward trend of infected cases in Bangladesh using FPM in the first wave in 2020<sup>34</sup>. The upward trend is alarming for Bangladesh in both infection and death cases at this second wave. Actual daily CFR showed almost a constant trend till Jun and slightly increased in July 2021 but predicted daily CFR exhibits roughly constant trend in Bangladesh till September 30, 2021. The roughly constant trend of daily CFR indicated a number of deaths over the number of infections by COVID-19 disease are roughly the same over time. Actual and predicted daily RDR increased from the beginning of the COVID-19 outbreak in Bangladesh but started decreasing from the beginning of the second wave. The decreasing trend of daily RDR indicates the recovery rate is getting lower compared to deaths at this ongoing second wave of COVID-19 in Bangladesh.

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