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CONTENTS

COVID-19 Pandemic Situations and Predictions in Bangladesh

Md Hasinur Rahaman Khan
Institute of Statistical Research and Training
University of Dhaka, Bangladesh
Email: *hasinur@isrt.ac.bd*

Abstract

It is evident that the COVID-19 pandemic has affected everyone regardless of race, nationality, and economic status. This paper aims at analyzing the current situation of Bangladesh and predicting infections and deaths for short, moderate, and longer periods of time using Trajectory-Pathway Strategy (ITPS), polynomial regression and Susceptible-Infectious-Removed (SIR) methods and the COVID-19 data extracted from different sources as of April 22, 2021. The case positivity rate increased to 23.6 per cent on April 9 from its lowest 2.3 per cent on February 9, 2021. The tests per head remain low when compared to other south Asian countries. We found that the potential pathway of infections for Bangladesh currently matches the actual infection pathways for Sweden and Pakistan. The ITPS suggests that by May 21, 2021, Bangladesh will cross 916,830 cases and 13,386 deaths, similar to Sweden's pathway, while by May 22, 2021, these figures will be 772,381 and 11,277 respectively if Bangladesh follows Pakistan's pathway. The polynomial regression predicts that by the end of April 2021, total number of infections and deaths will be 851,986 and 11,669, respectively and the required hospital beds and ICU beds will be 20,053 and 4,011, respectively.

Keywords: Bangladesh, COVID-19 Deaths, Infections, Prediction

Introduction

The severe acute respiratory syndrome coronavirus (SARS-CoV-2) is an infectious disease first identified in December 2019 in Wuhan, the capital of China's Hubei province. This disease spread first in Wuhan in December 2019 and then spread globally since February 2020, resulting in the ongoing coronavirus pandemic. For most people, COVID-19 infection will cause mild illness, such as fever, cough, and shortness of breath. However, it can make some people very ill and can be, in its worst scenario case, fatal. Older people and those who have pre-existing medical conditions (such as cardiovascular disease, chronic respiratory disease, or diabetes) are at risk for severe cases of the disease (WHO, 2020). Other common symptoms may include fatigue, muscle pain, diarrhea, sore throat, loss of smell, and abdominal pain.

Bangladesh found its first coronavirus cases on March 8, 2020. The first three coronavirus cases were confirmed by the IEDCR at a press conference (IEDCR, 2021). The cases included two men and one woman, who were aged between 20 and 35. Of these, the two men had recently returned from Italy and the woman was a family member of one of these two men. Approximately 111 tests were conducted on that day in Bangladesh. On March 16, the country detected three more cases of COVID-19, taking the total number of infected individuals to eight. The first death due to coronavirus occurred on March 18, when a 70-year-old man died of the disease. To slow down the spread of the virus, Bangladesh, like many other countries, adopted several measures such as compulsory lockdowns, quarantines at home, social distancing, and bans on domestic and international flights. This was followed by shutting down schools and colleges, and a week later all remaining offices were closed, resulting in a national lockdown (IEDCR, 2021).

The first peak in infections took place on July 2, 2020, when 4,019 cases were identified while the second wave began in March 2021. As of April 22, 2021, the number of COVID-19 infections and deaths were 736,025, and 10,780 respectively. The government announced a strict lockdown on April 14 and extended that to two weeks. For people in one of the most densely populated countries, it is a difficult task to maintain social distance, despite the closing of educational institutes, offices, and markets. These closures may contribute considerably to reducing the spread of the pandemic, but people are still at risk when traveling in crowded public transport and living cheek by jowl in urban slums. Additionally, the public healthcare system in Bangladesh is inadequate and overburdened. According to the World Bank (2020), in 2015 Bangladesh had 0.8 hospital beds for every 1000 people.[1]

A considerable amount of research on COVID-19 using Bangladesh data has already been published (Khan and Hossain, 2020b; Ali et al., 2020; Khan and Howlader, 2020a; Khan et al., 2020; Khan and Howlader, 2020b). Recently, Islam et al. (2020) proposed a model to measure the risk of infectious disease and predict the risk of COVID-19 transmission using data from Bangladesh and four other countries - the United States, Australia, Canada, and China. Paul et al. (2020) proposed a Susceptible-Exposed-Infectious-Removed (SEIR) epidemic model that accommodates the effects of lockdown and individual based precautionary measures and used it to estimate model parameters from the epidemic data for three South Asian countries - Bangladesh, India, and Pakistan. However, their prediction model for Bangladesh may not give reasonable results because of the small sample used. Mamuna and Griffiths (2020) discussed possible suicide prevention strategies when the first COVID-19 suicide case in Bangladesh took place. None of these studies analyzed the current situation with regard to the coronavirus in Bangladesh, nor made direct predictions for incidence, deaths, hospital ICU beds, number of severe patients, etc. This paper fills that gap.

There are a number of models for infectious diseases available in literature and have been used primarily for countries where the number of cases is very high.[2] Particularly, a number of studies (Kucharski et al., 2020; Chinazzi et al., 2020; Roosa et al., 2020; Grasselli et al., 2020; Boldog et al., 2020; Hui et al., 2020; Xie et al., 2020; Lourenco et al., 2020; IHME, 2020, Phua et al., 2020; Barra-Sandoval et al., 2021; Guo and He, 2021; and Roberto et al., 2021) have used different mathematical models to determine the spread of the disease and predict the number of incidence and health care facilities in tackling COVID-19 spread. In this study, we will use a polynomial regression model, the Infection Trajectory-Pathway Strategy method and a Susceptible-Infectious-Removed (SIR) model to predict the total number of infected people, deaths, and the number of hospital and ICU beds. It should be noted that, given the weak existing healthcare infrastructure and the spread of the virus, the government may find it difficult to manage the spread in light of the predicted statistics.

Data Source

The data used for the current study has been from the Esri Living Atla (Dong and Gardner, 2020). This is a data repository maintained by the Johns Hopkins University (Johns Hopkins University, 2021a, 2021b) until April 22, 2021. For prediction purposes, we used data from April 1 to 15. Several other secondary data sources have been used such as the IEDCR (IEDCR, 2021), Our World in Data (Max Roser and Ortiz-Ospina, 2021), and Worldometers (Worldometers.info, 2021).

Methodology

Basic statistical analysis, trend line charts, correlation, and *t*-tests have been used in this study. For a prediction of COVID-19 infections and deaths for a short and moderate period of time, a higher order polynomial regression model and the Infection Trajectory-Pathway Strategy (ITPS) methods, respectively, have been used. For a prediction of COVID-19 infections and deaths for a longer period of time, the SIR model has been used. We implemented these three prediction techniques to forecast mainly the cumulative number of COVID-19 infections and deaths in Bangladesh. We believe that knowing predicted figures during different time intervals can help the authorities to take the appropriate and necessary actions that will reduce the spread of the disease for these three time periods that are considered.

Most models infer trends regarding an epidemic in a given location by looking at the current status of the disease, and then applying a mathematical approximation of its likely future path. This is drawn from experiences in other locations and/or assumptions about the population, transmission, and public health policies in place. Here, the second order polynomial regression model has been used with confirmed orthogonality to help arrive at uncorrelated regression coefficients. Polynomial regressions, along with fitting trends, have been used in forecasting diseases by many researchers (Pandey et al., 2020; Johannes, 2008; Howard, 1943). A second order polynomial regression model has been proven to be an extremely effective and useful tool to provide predictions for a short period of time, e.g., 15-30 days. It can be used for predicting COVID-19 infections, deaths, hospital beds and ICU beds. The two-degree polynomial regression model is given by:

$$\hat{f}(x) = \hat{\beta}_0 + \hat{\beta}_1 x + \hat{\beta}_2 x^2$$

where x is a variable that represents the number of days, β_0, β_1, and β_2 represent the estimated regression coefficients, and $\hat{f}(x)$ is the predicted total number of infections or deaths. We have also obtained 95% confidence interval estimates for the total number of infections or deaths. This method is used to fit the trend of infections and deaths for Bangladesh COVID-19 data. Then, based on many studies including Phua et al. (2020), we estimated thehospital and ICU patients as 20% and 4% of active COVID-19 infections, respectively.

The SIR model is a common epidemiological modeling technique that divides an estimated population into different groups or compartments at time *t*. These include "susceptible" [S(t)], "infected" [I(t)], and "removed/recovered" [R(t)]. Then the technique applies a set of mathematical rules about how people move from one compartment to another, using assumptions about the disease process, social mixing, public health policies, and other factors. The above models have taken center stage in many key policy discussions surrounding COVID-19, largely due to the unprecedented nature of the situation. Countries use models to shape their health system responsesas the virus spreads in their communities.

More specifically, the dynamic model is expected to consider the existing growth rate (e.g., exponential in recent months for Bangladesh) and several covariates such as the planned number of tests, measures taken for social distancing, healthcare facilities, etc. would be used. Such a model family comprises many models such as SIR, SIER, or Susceptible-Infectious-Removed-Deceased (SIRD) which have been used recently in many studies (Loureno et al., 2020; IHME, 2020). The dynamics of COVID-19 seem to be much faster than the dynamics of birth and death. Therefore, births and deaths are omitted and an SIR system without these vital dynamics (birth and death) is used in this context of the pandemic. The simple SIR model can be discussed briefly below. It is assumed that the total population N(t) = S(t) + I(t) + R(t) is fixed, such that the differential equation becomes

$$0 = \frac{dN}{dt} = \frac{dS}{dt} + \frac{dI}{dt} + \frac{dR}{dt}, \qquad \forall t \geq 0, \text{ where}$$

$$\frac{dS}{dt} = -\beta\ S(t)I((t)$$

$$\frac{dI}{dt} = -\beta\ S(t)I((t) - k\ I(t)$$

$$\frac{dR}{dt} = kI((t)$$

where β is the average number of contacts per person per time and k is the transition rate that is assumed to be proportional to the number of infectious individuals. These two rates change as time changes. Under this method, the only way that a person can leave the susceptible group is to become infected, and the infected group will either recover or die. Those who have recovered from the disease are included in the immune category. The model begins with initial values of S(t = 0), I(t = 0), and R(t = 0). These are the number of people in the susceptible, infected, and removed categories at time period zero. If the SIR model is assumed to hold at all times, these initial conditions are not independent. As a result, the flow model updates the three variables for every point in time with set values for β and k.

In addition, a new Infection Trajectory-Pathway Strategy (ITPS) method, as proposed in Khan and Hossain (2020a), has been implemented to predict total COVID-19 infections, deaths, and other statistics in Bangladesh for a moderate period of time. These methods have been implemented under the assumptions that no major interventions, such as strict lockdowns, or rapid decrease or increase in tests, are imposed over the predicted period. We have also used this method to fit the trend of infections and deaths for Bangladesh COVID-19 data by observing the trajectory of infections and deaths.

Analysis

In Bangladesh, the first COVID-19 case was detected on March 8, 2020, and the government announced a national unofficial lockdown 17 days later. To curb the spread of the infection, this lockdown was called well in advance, compared to many other countries, including India and Pakistan. Even before the lockdown, a majority of schools, colleges, markets, cinema halls, etc. were already shut down in Dhaka and other parts of the country. Nonetheless, Bangladesh had its first peak of COVID-19 cases in the month of July. The highest death toll was 64 and took place on June 30, 2020, while the highest number of cases, 4,019, took place on July 2 of that year. The effect of the first peak went on until October or November, while another peak was about to start in November or December but did not become significant. However, three months later a clear second wave began in March 2021.

In order to decrease infections, the government announced a strict lockdown on April 14 for one week, and then extended this to April 28. The government banned all movement and urged people to stay at home. Citizens were allowed to step out only in emergency situations. All these steps were taken in the hope of flattening the curve of infected cases and to limit the exponential growth of the patients in Bangladesh. The month-wise rate of infected cases, deaths, recoveries, and tests are reported in Figure 1.

The highest number of cases per hour (>189) took place in April 2021, while the second highest number of cases per hour (about 137) took place in June last year. So far, the highest number of deaths per 10 hours (>26) took place in April 2021, while the second highest number of deaths per 10 hours (17) took place in July 2020. So far, the highest number of recoveries per hour (about 152) was reported in April 2021, while the second highest number of recoveries per hour (>103) occurred in December 2020.

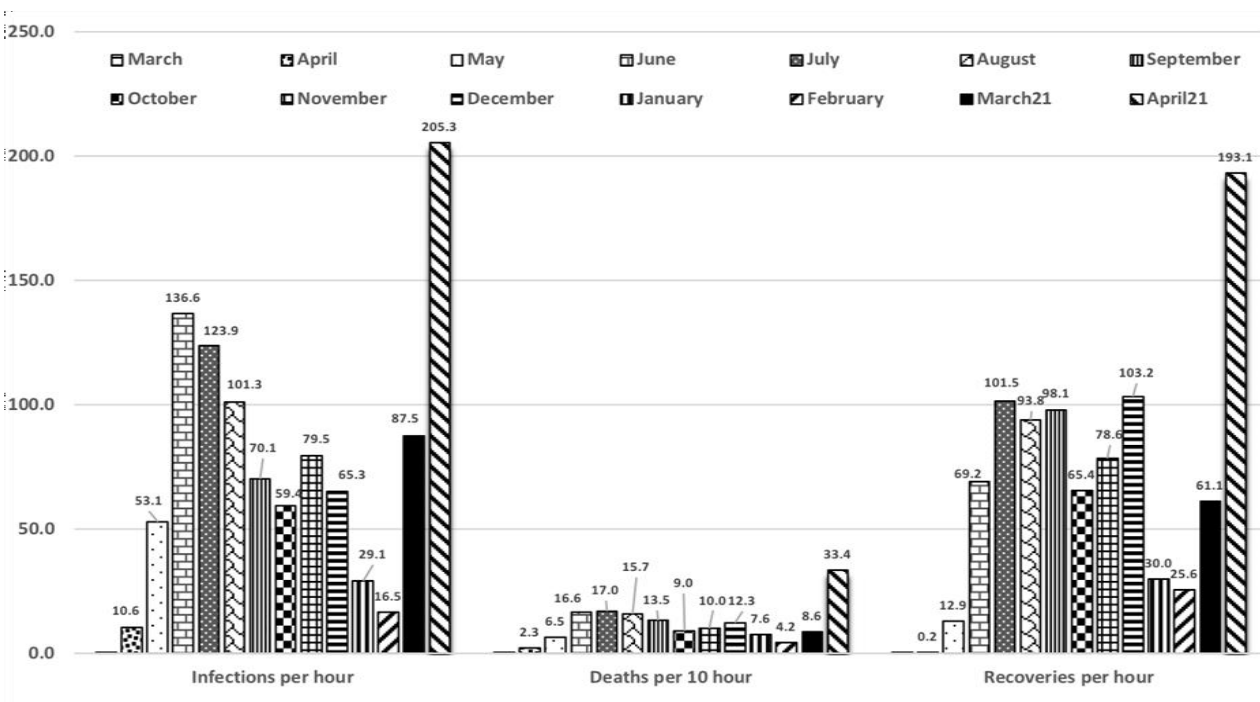

Figure 1: Month-wise rates of infections, deaths, recoveries, and tests of COVID-19 in Bangladesh (as of April 22, 2021)

There were 727,731 infected cases and 10,587 deaths reported in Bangladesh as of April 20, 2021, with 12.2% of the cases being active. This is similar to the global percentage of active cases at 12.8% (Dong and Gardner, 2020). On that date, the recovery rate was 86.3%, the test positivity rate was 13.9%, and the infection fatality rate was 1.45. Globally, Bangladesh currently stands in 33rd position in terms of infection cases, 38th position in terms of deaths, and 50th position in terms of tests. More than 50% cases are from Dhaka division (IEDCR, 2021). The sex ratio (males to females) among the infected population is found to be 71. Since March 2021, the number of infections and deaths have increased significantly with much higher rates compared to 2020 (see Figure 1). The *Re* is called the basic reproduction rate or the expected number of secondary cases produced by a single infectious individual during the infectious period within a completely susceptible population. If *Re* is greater than 1, then epidemic increases exponentially, but if *Re* is less than 1, then the disease is predicted to die out. We found the highest *Re* value of 8.95 taking place on March 17, 2020, and the lowest *Re* value 0.12 on March 29, 2020 (see Figure 2). The *Re* is found to be 0.86 on April 22, 2021, with the median value of *Re* at 1.03. All *Re*'s are estimated based on the Cori model.

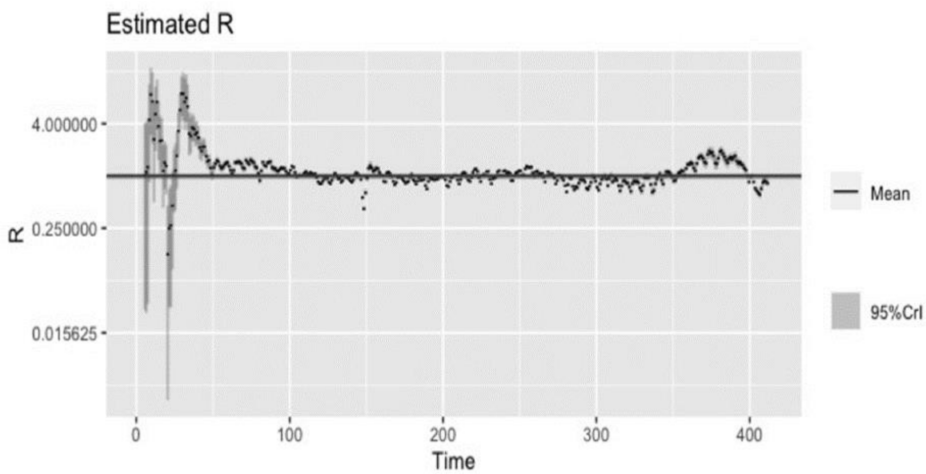

Figure 2: Daily instantaneous effective reproduction numbers (Re) of COVID-19 in Bangladesh (as of April 22, 2021)

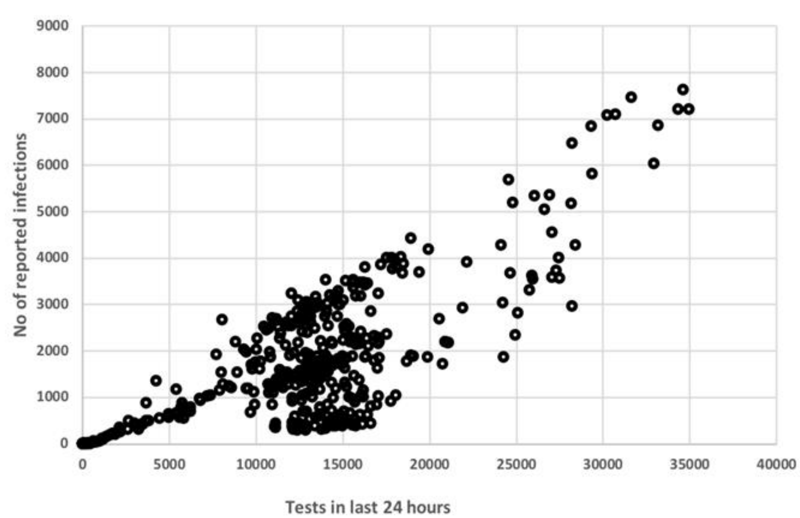

Figure 3: Scatter plot between number of tests and reported infections of COVID-19 in Bangladesh (as of April 20, 2021)

Testing is the only effective window into the COVID-19 pandemic and how it is spreading. When a disease becomes a pandemic, early testing can lead to a swift identification of cases, quick treatment for those infected, and immediate isolation to prevent spreading and to trace their contacts. Early testing also helps to identify anyone who has come into contact with infected people so that they, too, can be quickly treated. China, South Korea, and Taiwan have followed this procedure and used it as one of the most important tools in the fight to slow and reduce the spread and impact of the virus. As expected, Figure 3 shows that a very strong and positive correlation is found between the number of tests conducted daily and the reported infections in Bangladesh. The correlation coefficient is 0.76, based on the data reported as of April 20, 2021. As of April 20, Bangladesh has tested only 5,221,275 case samples, which is at a rate of 31,454 per million, and much lower than many countries including India and Pakistan (Max Roser and Ortiz-Ospina, 2021). The number of COVID-19 tests has also been increased considerably in the months of March and April 2021.

Prediction with Infection Trajectory-Pathway Strategy

Bangladesh is one of the 33 countries that have passed the threshold of 700,000 confirmed cases, with many more countries on the cusp (Max Roser and Ortiz-Ospina, 2021). Figure 4 displays the infection trajectory since the 100-case mark for Bangladesh, along Pakistan and Sweden, based on data reported on April 20, 2021.

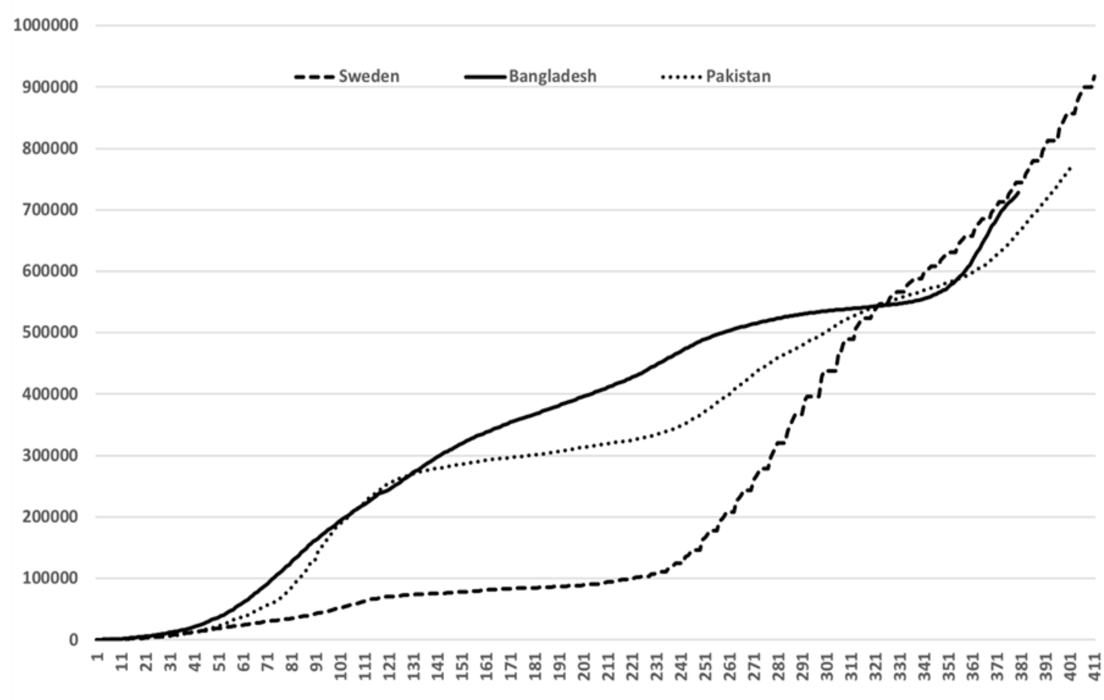

Figure 4: Infection trajectory (number of days versus cumulative infections) in Bangladesh, Pakistan, and Sweden since 100 confirmed cases

Pakistan and Sweden have trajectory pathways or experiences that are similar to Bangladesh, and this is evident from the 325 days of data after the 100-case mark was crossed in each country. In terms of infections, both countries are well ahead of Bangladesh, and Bangladesh is likely to experience their pathways in future. By comparing such trajectories, we would be able to see a clearer picture of how quickly the infections may increase in the future.

While Bangladesh is on the same trajectory, but well behind the other two, it is possible to gauge how quickly the virus cases may increase based on this trajectory. This procedure is known as the ITPS (Infection Trajectory-Pathway Strategy) and discussed in Khan and Hossain (2020a).

Bangladesh crossed the 100-case mark on April 7, 2020, exactly one month after the first case that was identified. However, Figure 4 shows that Bangladesh could follow the same pathway of infection trajectory that was experienced by the two countries – Sweden which is 31 days ahead and currently has 916,830 COVID-19 infections, and Pakistan which is 32 days ahead and on April 22, Pakistan has 772,381 COVID-19 infections. Hence after 31 and 32 days the predicted infections for Bangladesh can easily be estimated and these are reported in Table 1. Bangladesh's pathway appears to be closer to Sweden's than to that of Pakistan. This table also gives the predicted deaths estimated based on the current case fatality rate of 1.46% in Bangladesh, as reported on April 20, 2021 (Johns Hopkins University, 2021b). If all the assumptions regarding COVID-19 infection growth are kept similar to Sweden and Pakistan for Bangladesh, then the ITPS prediction method suggests that Bangladesh may exceed 916,830 cases and 13,386 deaths, in its worst-case scenario, by May 21, 2021, while infection and death toll may cross 772,381 and 11,277 respectively in its best-case scenario, by May 22 of that year.

Table 1: Predicted total infections and deaths based on ITPS method

Date	Predicted total Infections	Predicted total deaths
May 21, 2021	916,830	13,386
May 22, 2021	772,381	11,277

Prediction with Polynomial Regression Model

Short-term predictions for infected people, hospital beds, ICU beds, and deaths have been made using a second-degree polynomial regression. Table 2 shows the predicted numbers at 95% confidence intervals. According to Phua et al. (2020), 12% of all reported cases need ICU admissions while 13.4% of all patients are treated as severe. However, at present, many studies have found that 20% of all infected may need hospital beds while only 4% of all patients need ICU service. All patients who have a severe case of the disease need hospital admissions, in addition to some other symptomatic patients demonstrating sufficient symptoms.

In this paper, we have predicted the cumulative infections for a 15-day time interval - April 16 to 30, 2021. This prediction was based on the April 1-15, 2021, dataset since the model is reasonably good for capturing and predicting short-term trends. In particular, Khan (2020a) had used this model to publish a daily report on the COVID-19 situation in Bangladesh, with predictions for infections conducted on June 6, 2020. The predicted figures had matched well with observed figures on June 15, 2020 (Khan, 2020b).

Our predictions for hospital and ICU beds have been carried out based on the predicted number of patients. We assume that each patient may occupy a single bed. For this study we estimated the total hospital and ICU patients as 20% and 4% of the active number of infections. The rate of active infection in Bangladesh was 14.1% on April 15, 2021. We used this rate as the fixed rate for the prediction period. Prediction of total deaths has also been carried out in the same way using a second-degree polynomial regression.

This prediction method tells that the total number infected people and deaths in Bangladesh by April 30, 2021, may cross 851,986 (95% CI: 839,137-864,835) and almost 11,669 (95% CI: 11,642-11,695) respectively, while the number of hospital and ICU beds may cross 20,053 (95% CI: 19,751-20,355) and 4,011 (95% CI: 3,950-4,071) respectively. These figures are estimated to be 798,395 (95% CI: 788,777-808,014), 18,792 (95% CI: 18,565-19,018), 3,758 (95% CI: 3,713-3,804), and 11,071 (95% CI: 11,051-11,091) respectively by April 25, 2021. Although the relationship between deaths and country's intensive care bed capacity is very important in calculating the predicted deaths, it is likely that the actual deaths could be higher than the predicted numbers since Bangladesh does not have enough hospital and ICU beds to meet the required demand (The Daily Dhaka Tribune, March 21, 2020; Nafseen, 2018).

Table 2: Prediction for COVID-19 infections, hospital beds, ICU beds, and deaths for April 16-30, 2021, in Bangladeshusing a polynomial regression method

Date	Projected Infections			Projected Hospital Beds			Projected ICU Beds			Projected Deaths		
	Total	Lower of 95% CI	Upper of 95% CI	Total	Lower of 95% CI	Upper of 95% CI	Total	Lower of 95% CI	Upper of 95% CI	Total	Lower of 95% CI	Upper of 95% CI
16-Apr	715010	708591	721430	19819	19641	19997	3964	3928	3999	10158	10145	10170
17-Apr	723445	716835	730054	19443	19265	19620	3889	3853	3924	10249	10236	10262
18-Apr	732087	725249	738925	19059	18881	19238	3812	3776	3848	10343	10329	10357
19-Apr	740937	733830	748043	17439	17272	17607	3488	3454	3521	10439	10425	10454
20-Apr	749994	742576	757412	17652	17478	17827	3530	3496	3565	10538	10523	10553
21-Apr	759259	751487	767031	17871	17688	18053	3574	3538	3611	10640	10624	10655
22-Apr	768732	760563	776901	18093	17901	18286	3619	3580	3657	10744	10727	10760
23-Apr	778412	769802	787022	18321	18119	18524	3664	3624	3705	10850	10833	10868
24-Apr	788300	779207	797393	18554	18340	18768	3711	3668	3754	10959	10941	10978
25-Apr	798395	788777	808014	18792	18565	19018	3758	3713	3804	11071	11051	11091
26-Apr	808698	798513	818883	19034	18794	19274	3807	3759	3855	11186	11165	11207
27-Apr	819209	808416	830001	19282	19028	19536	3856	3806	3907	11302	11280	11325
28-Apr	829927	818487	841367	19534	19265	19803	3907	3853	3961	11422	11398	11446
29-Apr	840853	828727	852978	19791	19506	20076	3958	3901	4015	11544	11519	11569
30-Apr	851986	839137	864835	20053	19751	20355	4011	3950	4071	11669	11642	11695

Prediction with SIR Model

Suitable and dynamic models are generally used for precision in prediction. Figure 5 shows that the SIR model was implemented on the observed data collected on April 22, 2021, under the similar assumptions Bangladesh is expected to reach 68,000 daily infection cases by May 31; 23,000 by June 30, and 3,400 by the end of July 31, 2021, which translates to a corresponding number of deaths following the contemporary case fatality rate which was 1.46% on April 22 of that year.

Discussions and Conclusions

This paper presented basic analysis and results of the current COVID-19 situation in Bangladesh during the second wave of the virus that started in March 2021. The paper proposed an ad-hoc prediction strategy known as Infection Trajectory-Pathway Strategy (ITPS) for predicting total infections and deaths suitable for a moderate period of time (one month or 45 days). The ITPS is a new method in predicting infections under the assumptions that the predicted country will follow the infection trajectory line (or, indirectly, the exact infection growth rates) of countries that have already experienced the same infection trajectory.

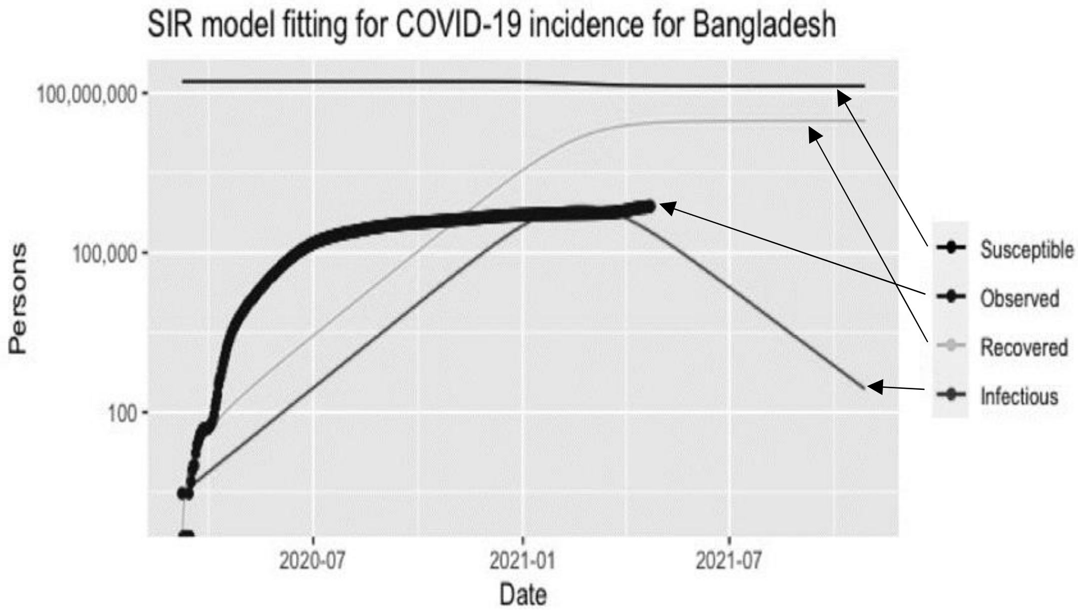

Figure 5: Prediction for COVID-19 infections by SIR model

While the world grapples with the containment of the COVID-19 outbreak, Bangladesh may not be doing well in this regard as the number of tests done as of April 20, 2021, is over just 5,231,000 which is a low number compared to the neighboring countries, such as India or Pakistan. Despite having a very strong positive correlation (0.76) between the daily tests and number of infected people, the growth rate of tests in Bangladesh is considerably low. Although the capacity of tests has increased to double from March to April 2021, this needs further rapid increase for a quick detection of cases. This will help to restrict the spread by isolating those infected and quarantiningthose who are susceptible. Unfortunately, little contact tracing, isolation and quarantine have been done during this ongoing second wave of COVID-19.

A prediction on the number of severe and ICU patients could help the government of Bangladesh to prepare an adequate number of hospital beds, including ICU beds, and health staff to tackle the potential demand of COVID-19 patients. The findings in this study provide an indication of the challenges that the Bangladesh healthcare system will face if the COVID-19 epidemic progresses unabated. To treat critical patients, fully functional ICU beds are crucial. These ICU beds are not useful in the absence of an adequate number of trained critical healthcare workers, medical supplies, and personal protective equipment (PPE) that are needed for crisis management. Therefore, the government, hospital administrators, and policy makers must work with ICU doctors and nurses to prepare for a substantial increase in critical care bed capacity. The government must use unprecedented methods to protect healthcare workers from nosocomial transmission and physical exhaustion, including potential mental health issues.

Endnotes

[1] By way of comparison, India has 0.7 (2011), Pakistan has 0.6 (2012), Sri Lanka has 3.6 (2012), the US has 2.9 (2012), and China has 4.2 (2012) beds per 1,000 people.

[2] These include China, Italy, Spain, the UK, Germany, and the US.

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