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RESEARCH ARTICLES

Estimation and prediction of doubling time for COVID-19 epidemic in Bangladesh: a modelling study of first 14 month's daily confirmed new cases and deaths

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Abstract

Background: The doubling time is a reliable indicator to estimate the rate at which the pandemic is spreading. We evaluated and predicted the doubling time for the daily COVID-19 cases and deaths in Bangladesh.

Methods: Publicly available daily data on COVID-19 new cases from 8 March, 2020 to 14 February, 2021 and the daily deaths data from 18 March, 2020 to 14 February, 2021 were used to predict doubling time based on records from seven days prior. Then, short-term predictions for the next 14 days (1 to 14 February, 2021) were performed to validate the accuracy of our prediction. Finally, using the doubling time data up to 14 February, 2021, a two months (15 February- 15 April, 2021) prediction was made for both daily new COVID-19 cases and deaths.

Results: The median doubling time for daily new COVID-19 cases and deaths were 90.51 and 86.02 days respectively in the entire period. The doubling period for cases was lowest in the second to third week of March, 2020 [ranged 2.33-8.43 days] and longest in the second week of March, 2021 [ranged 834-2187 days]. Our prediction suggests that the doubling time for daily confirmed new COVID-19 case will be 1310.33 days [95% CI: 854.33 - 1766.32] and deaths will be 683.04 days [556.05 - 810.03] on 15 April, 2021 in Bangladesh.

Conclusion: Our prediction is based on current testing strategies. Any changes in daily number of tests or sudden changes of the dynamics of COVID-19 transmission would affect these predictions.

Keywords: COVID-19, Doubling Time, Prediction, Bangladesh.

Introduction

Since its first case detection in Wuhan, Hubei Province, China in December 2019, the Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) has caused the emergence of the novel coronavirus disease 2019, referred to as COVID-19. On 30 January, 2020, the World Health Organization (WHO) declared COVID-19 a public health emergency of international concern, and then subsequently, a pandemic on 11 March, 2020 [1]. The pandemic has rapidly swept across the globe infecting more than 122 million people, and more than 2.69 million people died as of 20 March, 2021 [2]. Since its rapid spread outside of Mainland China at the beginning of 2020, COVID-19 caused a serious global public health threat [3–5]. At its early phase in China, the number of cases were double at every 7.5 days, indicating a faster transmission of the virus [6]. The rapid spread of COVID-19 has emerged new infections in almost all South-Asian regions, including Bangladesh, from the beginning of March, 2020 [7].

Understanding the epidemiological changes of COVID-19 pandemic is crucial for the preparation and implementation of policies and strategies aimed towards slowing down the spread of pandemic, and subsequently the flattening of the curve [8]. Several approaches have been made by researchers worldwide to estimate and predict the spread of COVID-19 [9–12]. One of these approaches is estimating the doubling time for COVID-19 cases and deaths figures [13,14], which refer to the time required for the number of cases/deaths to be double from the starting day, based on the rate of cumulative increases in number of cases/deaths. If the pandemic grows exponentially with a constant growth rate, the doubling time remains constant and equal [15]. Doubling time for confirmed cases shows the number of days that have passed since the number of cases were half [13,16]. Similarly, doubling number of deaths shows the number of days that have passed since the number of deaths was half of the current count [14]. Shorter doubling time indicates a faster spread of the virus.

Bangladesh reported 5.65 million infected and 8,624 confirmed COVID-19 deaths as of 20 March, 2021 [17]. The first case was detected on 8 March, 2020 [18] and since then, Bangladesh reached 100 cases on 9 April, and doubled the cases during the next two days [19]. Moreover, to the best of our knowledge, no research has been published on the speed of COVID-19 transmission for the Bangladeshi population. Findings of such a study can help policy makers at national level to better prepare for the pandemic by adjusting COVID-19 dedicated hospital beds, Intensive Care Unit beds, Personal Protection Equipment (PPE) distributions, and maintaining a steady supply and availability of essential medications for COVID-19 management. The objective of this study was to evaluate and predict the doubling time for daily confirmed new cases and deaths in COVID-19.

Materials and Methods

Study design and data source

We collected publicly shared daily data from the website of Directorate General of Health Services (DGHS) Bangladesh [20] and Institute of Epidemiology Disease Control and Research (IEDCR) [21]. The daily data on confirmed COVID-19 new cases from 8 March, 2020 to 14 February, 2021 and the daily data on confirmed COVID-19 deaths from 18 March, 2020 to 14 February, 2021 were used and their doubling times were calculated seven days prior to conducting this study.

Calculation of doubling time

Doubling time was calculated based on records from seven days prior to conducting this study, using the following formula [13,16].

$$D_{(t_2)} = (t_2 - t_1)\left(\frac{\ln(2)}{\ln\left(\frac{c_2}{c_1}\right)}\right) \dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Here, t_1 is the first day from when we start our calculation, t_2 is the day we want to calculate the doubling time for, c_1 is the cumulative number of cases or deaths for t_1, and c_2 is the cumulative number of cases or deaths for t_2. ln(2) is the natural logarithmic value of 2.

In Bangladesh, the first COVID-19 positive case was detected on 8 March 2020. A total of 3 cases were detected on that day. On 15 March, 2020, seven days from the first case identification, the total number of cases were 5. So according to the formula, if we calculate the case doubling time for 15 March, our t_1 would be 1, t_2 would be 8, c_1 would be 3, and c_2 would be 5.

So, the doubling time for the daily new cases for

$$15 \text{ March } 2020 = \left((8-1)\frac{\ln(2)}{\ln\left(\frac{5}{3}\right)}\right) = 7 * (0.6931/0.5108) = 9.50 \text{ (days)}$$

Using this method, the doubling time for the confirmed COVID-19 cases were calculated and analysed for each day from 15 March, 2020 to 14 February, 2021. Similarly, the doubling time for daily deaths were also calculated. The first confirmed COVID-19 death in Bangladesh was reported on 18 March, 2020. Since we are calculating doubling time based on the data from the last seven days, we started calculating doubling time for deaths from 25 March, 2020. So, the doubling time for daily deaths by COVID-19 was calculated and analysed for each day between the time periods of 25 March, 2020 to 14 February, 2021.

Model Accuracy and validation

To check the accuracy and validity of our prediction model, we performed a short-term 14 days [1 – 14 February, 2021] prediction of the doubling time for daily confirmed COVID-19 cases and deaths. Then, the predicted data with 95% confidence interval for both COVID-19 new cases and deaths were compared with the actual [calculated] doubling time data of the same time frame. ARIMA (1, 1, 1) (0, 0, 0) and ARIMA (0, 1, 0) (0, 0, 0) models were used as the best fitted model for cases and deaths respectively. The prediction models were selected following the time series best model selection criteria [22–24]. Although, the actual death doubling time showed fluctuation with predicted doubling time [Figure 1.b], the predicted doubling time for daily confirmed new cases showed good fit [Figure 1.a], where the actual doubling time falls in the 95% confidence limit of the predicted doubling time which ensures the accuracy and validity of our prediction model [Figure 1].

Finally, we used data up to 14 February, 2021 and predicted the daily confirmed new cases and deaths for the next two months [15 February to 15 April, 2021]. All the statistical analyses were performed using Excel 2019, R-programming 3.6.1 version and SPSS 20 version for Microsoft Windows.

Results

Trends analysis of doubling time for daily confirmed new COVID-19 cases and deaths

Starting on 15 March, 2020, the case doubling time was 9.5 days and later fell to 2.88 days after a week on 22 March, 2020 [Figure 2]. After that, the case doubling time steadily increased and reached to 80.21 days on 5 August, 2020, the highest it has been up until that date. It started to sharply decrease again and hit by 62.77 days on 12 August, and then started to increase gradually again. It reached 1034.32 days on 14 February, 2021. In the case of daily confirmed new COVID-19 deaths, the doubling time was 3.01 days on 25 March, 2020 and two peaks were observed later in that month. Then, it steadily increased until it was hit by another peak on 6 May, 2020 at 36.76 days, followed by decreased trends to 12.38 days on 19 May, 2020. Afterwards, the doubling time for deaths steadily increased with occasional minor drops and reached to 579.39 days on 14 February, 2021, the highest up until that date [Figure 2].

Monthly comparison of doubling time for daily COVID-19 confirm new cases and deaths

The monthly distribution of doubling time for daily new COVID-19 cases and deaths in Bangladesh indicates a Sine curve of doubling time [Figure 3]. Overall, the median doubling time for the daily new COVID-19 cases and deaths were 90.51 and 86.02 days respectively. The lowest median doubling time for cases was 4.74 days in March, 2020 with a lower variation (lowest value was 2.33), and the longest median doubling time for new case was 447.72 days in January, 2021 [maximum: 774.97], experiencing a larger variation. The doubling period for daily confirmed deaths in COVID-19 was 5.30 days in March [minimum: 3.01] and 298.74 days in January, 2021 [maximum: 376.73]. A significant Sine trend in median doubling time for both COVID-19 confirmed cases and deaths were observed during the whole period. The median doubling times for both daily new cases and deaths were lower in March, 2020. After that, it increased gradually and reached its highest in June, 2020 [Figure 3].

Prediction of doubling time for daily confirmed new COVID-19 cases and deaths

The doubling time for daily confirmed new COVID-19 cases and deaths was forecasted for the 15 February to 15 April, 2021, obtained by the best fitted ARIMA (1, 1, 1) (0, 0, 0) and ARIMA (0, 1, 0) (0, 0, 0) models respectively [Table 1, Figure 4]. Our prediction model suggested increased trends of doubling times for both daily new cases and deaths. It was predicted that the doubling time for daily confirmed new COVID-19 case will be 1310.33 days [95% CI: 854.33 - 1766.32] and deaths will be 683.04 days [556.05 - 810.03] on 15 April, 2021 in Bangladesh [Table 1 & Figure 4].

Discussion

In Bangladesh, on the date when the first positive case of COVID-19 was detected (8 March), the doubling period was 9.5 days. The daily deaths was first doubled within 3.01 days on 25 March, 2020. Our trend analysis of daily confirmed new cases and deaths showed a consistently increasing trend of doubling time. This finding is consistent with the report from the World Health Organization [25]. The case doubling time increased up to four times from 15 March, 2020, while the doubling time for deaths had increased up to 14 times during the study period. As the pandemic progressed, it took longer for the cumulative incidence cases to double in Bangladesh, which indicated an overall sub-exponential growth pattern. A consistent increase in the doubling time coincided with other preventive measures, including the use of face masks, area-based lockdowns, isolation, quarantine of suspected cases, and physical distancing where possible [13].

The increase in doubling time for new cases indicates a gradual decrease in the pace at which the virus is spreading [26]. Doubling time would remain the same if the pandemic is growing exponentially [13]. Yet, the slow but steady increase in doubling time for new cases in Bangladesh points towards a lower rate of new infection. Preventive measures are taken by the government, including area-based lockdowns, restrictions on public transport, limited opening of restaurants and shops, suspending conventional on-campus classes in all the educational institutes [27] and opting instead for online classes, keeping all non-essential services and offices closed, working alternate days, and introducing awareness programs for face mask use. Maintaining social distancing and hand washing, along with testing for COVID-19, seemed to have a positive impact in reducing the spread of the pandemic [28,29].

Figure 1. Comparison between actual and predicted doubling times to validate the accuracy of the prediction model for COVID-19 positive new cases and deaths in Bangladesh.

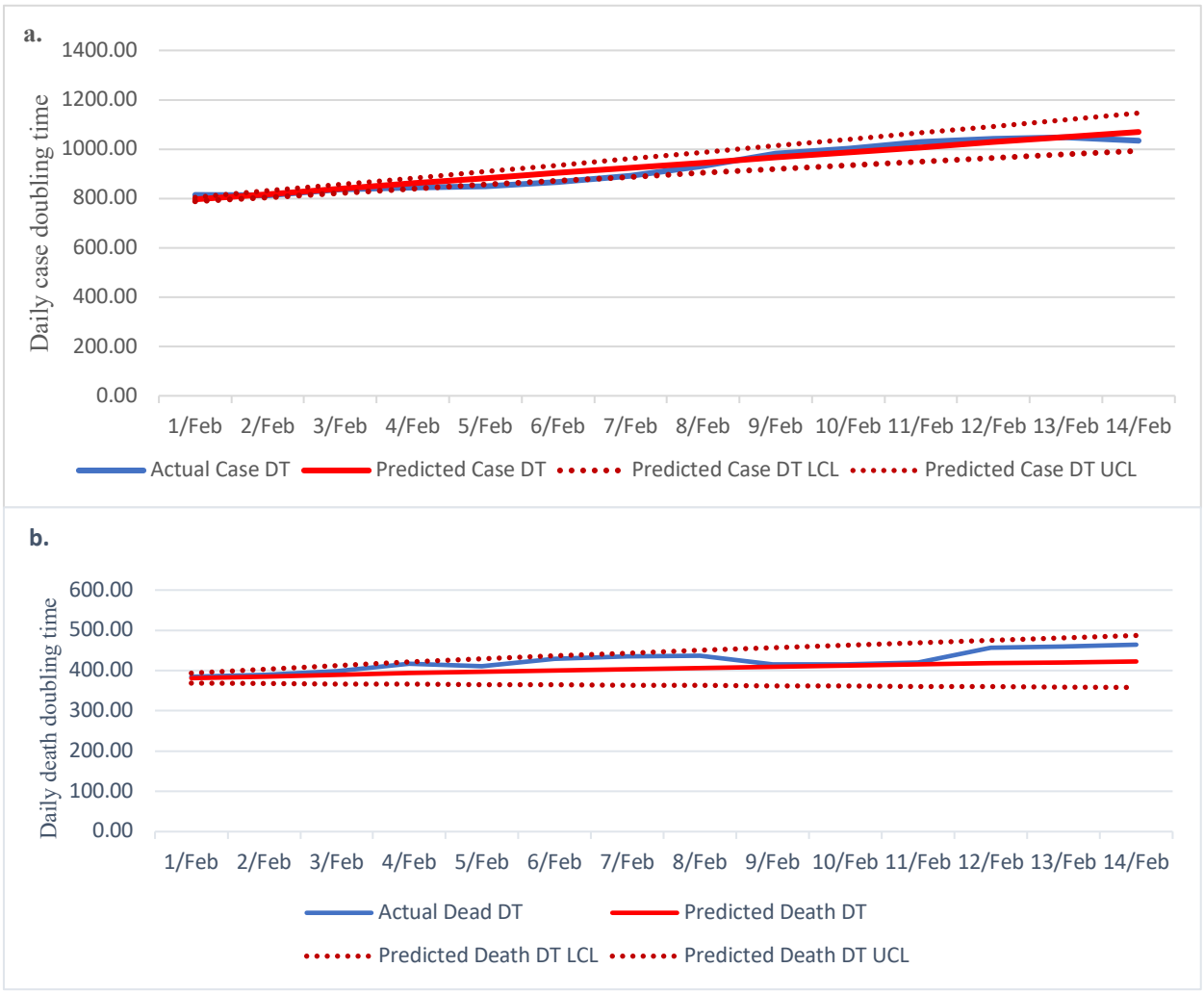

Figure 2. Trends of doubling time for daily confirmed new COVID-19 cases from 15, March, 2020 to 14 February, 2021 and deaths from 25 March, 2020 to 14 February, 2021 in Bangladesh.

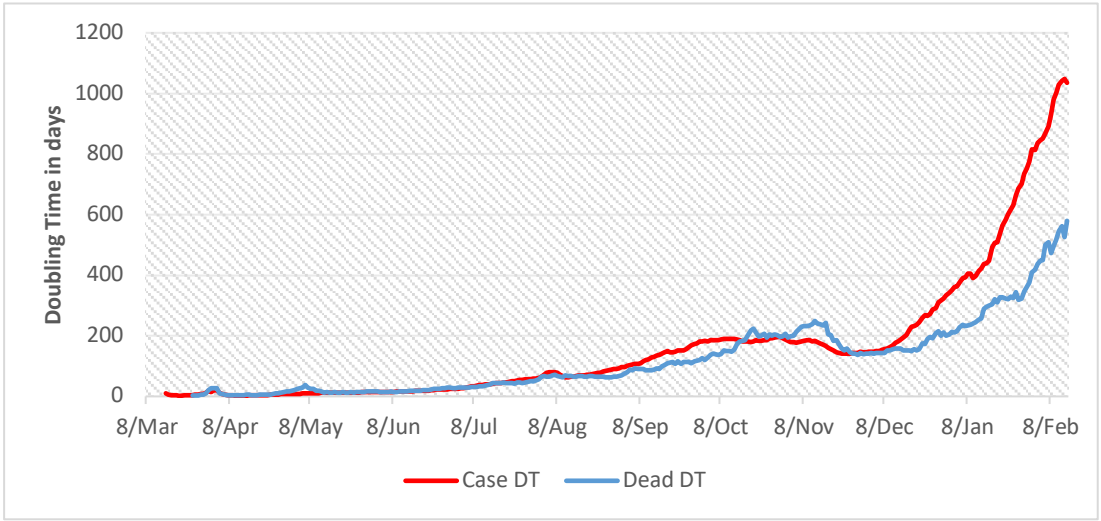

Figure 3. The boxplot for monthly doubling time for daily confirmed new COVID-19 cases and deaths from March, 2020 to February, 2021 in Bangladesh. The bottom and top of the box indicate the first and third quartiles value; the band inside the box is the median days.

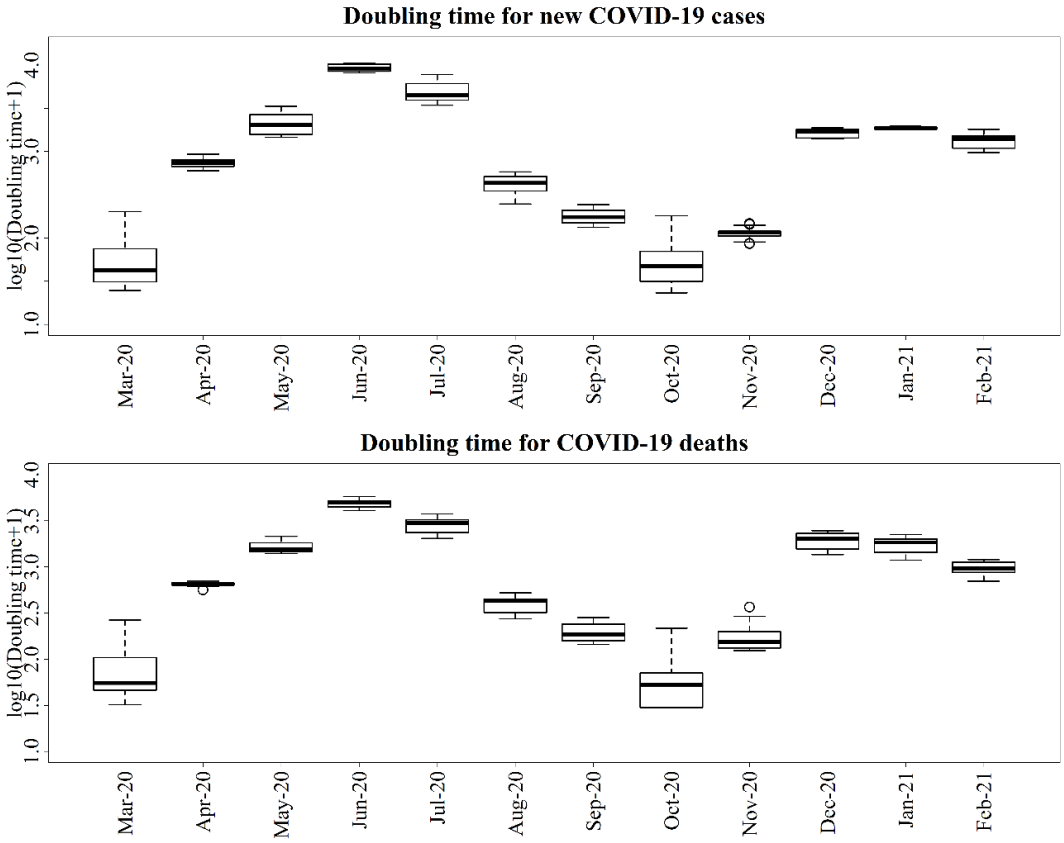

Figure 4. Two months (15 February to 15 April, 2021) prediction of doubling time for daily confirmed new COVID-19 cases and deaths in Bangladesh.

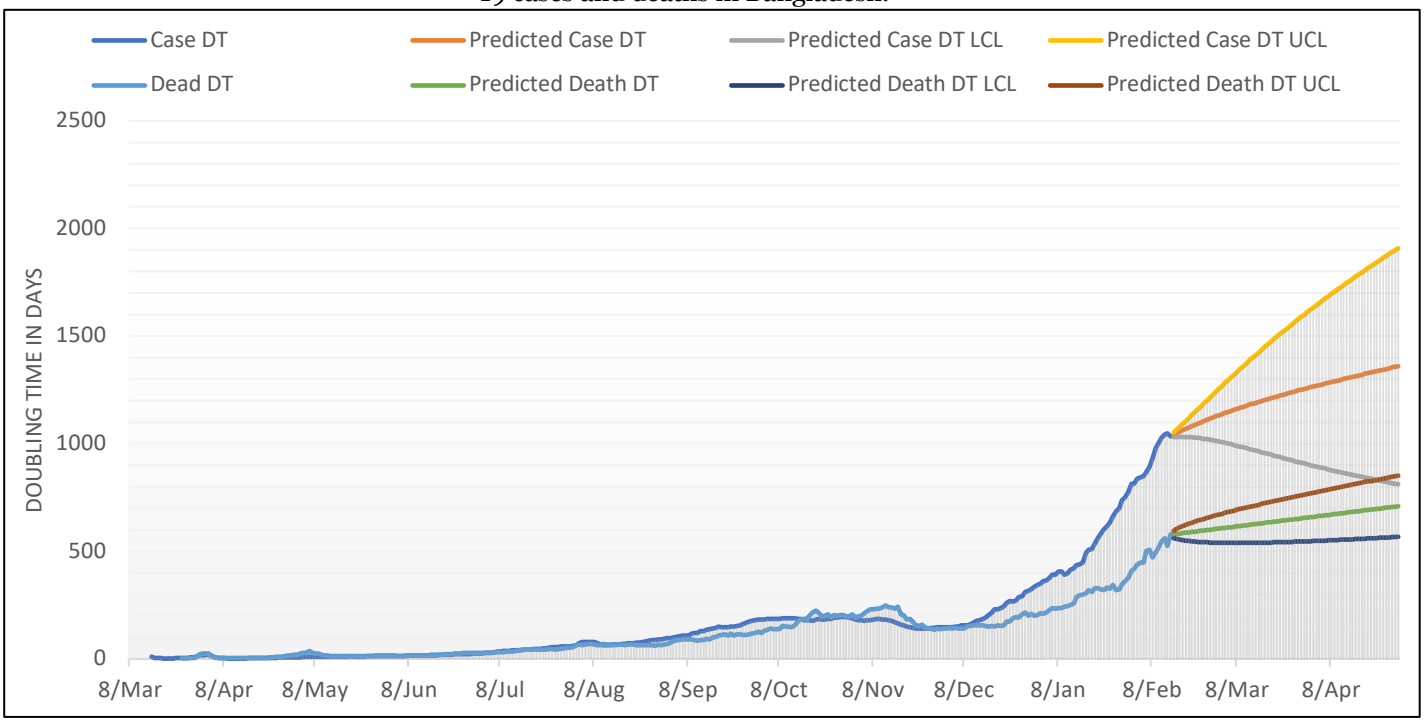

Table 1. Two months (15 February – 15 April, 2020) prediction of doubling time for daily confirmed new COVID-19 cases and daily confirmed COVID-19 deaths with 95% confidence interval.

Date	Daily Predicted New Cases with 95% confidence	Daily Predicted Deaths with 95% confidence	Date	Daily Predicted New Cases with 95% confidence	Daily Predicted Deaths with 95% confidence
15/Feb	1041.52 (1030.98 - 1052.05)	578.56 (561.60 - 595.52)	17/Mar	1202.46 (956.33 - 1448.59)	631.94 (540.63 - 723.26)
16/Feb	1048.55 (1031.42 - 1065.67)	580.99 (557.51 - 604.47)	18/Mar	1206.64 (952.56 - 1460.73)	633.71 (540.93 - 726.48)
17/Feb	1055.41 (1031.74 - 1079.09)	582.58 (553.92 - 611.23)	19/Mar	1210.78 (948.78 - 1472.78)	635.47 (541.25 - 729.68)
18/Feb	1062.13 (1031.73 - 1092.52)	584.38 (551.38 - 617.39)	20/Mar	1214.87 (945.01 - 1484.73)	637.23 (541.60 - 732.86)
19/Feb	1068.69 (1031.35 - 1106.03)	586.13 (549.28 - 622.98)	21/Mar	1218.92 (941.24 - 1496.60)	638.99 (541.97 - 736.01)
20/Feb	1075.10 (1030.61 - 1119.59)	587.90 (547.57 - 628.23)	22/Mar	1222.93 (937.49 - 1508.38)	640.75 (542.36 - 739.15)
21/Feb	1081.38 (1029.55 - 1133.21)	589.66 (546.13 - 633.19)	23/Mar	1226.90 (933.74 - 1520.06)	642.52 (542.76 - 742.27)
22/Feb	1087.53 (1028.19 - 1146.87)	591.42 (544.91 - 637.93)	24/Mar	1230.83 (930.00 - 1531.66)	644.28 (543.19 - 745.36)
23/Feb	1093.55 (1026.55 - 1160.55)	593.18 (543.87 - 642.50)	25/Mar	1234.73 (926.29 - 1543.17)	646.04 (543.63 - 748.45)
24/Feb	1099.45 (1024.66 - 1174.24)	594.95 (542.98 - 646.91)	26/Mar	1238.59 (922.59 - 1554.59)	647.80 (544.09 - 751.51)
25/Feb	1105.23 (1022.54 - 1187.91)	596.71 (542.22 - 651.20)	27/Mar	1242.42 (918.91 - 1565.92)	649.56 (544.57 - 754.56)
26/Feb	1110.90 (1020.23 - 1201.57)	598.47 (541.57 - 655.37)	28/Mar	1246.21 (915.25 - 1577.17)	651.32 (545.06 - 757.59)
27/Feb	1116.46 (1017.72 - 1215.20)	600.23 (541.02 - 659.44)	29/Mar	1249.98 (911.61 - 1588.34)	653.09 (545.56 - 760.61)
28/Feb	1121.92 (1015.06 - 1228.78)	601.99 (540.56 - 663.43)	30/Mar	1253.71 (908.00 - 1599.42)	654.85 (546.08 - 763.61)
1/Mar	1127.28 (1012.24 - 1242.32)	603.75 (540.17 - 667.34)	31/Mar	1257.42 (904.41 - 1610.42)	656.61 (546.62 - 766.60)
2/Mar	1132.55 (1009.29 - 1255.80)	605.52 (539.85 - 671.18)	1/Apr	1261.10 (900.85 - 1621.34)	658.37 (547.17 - 769.58)

3/Mar	1137.72 (1006.22 - 1269.22)	607.28 (539.60 - 674.95)	2/Apr	1264.75 (897.32 - 1632.18)	660.13 (547.73 - 772.54)
4/Mar	1142.81 (1003.05 - 1282.57)	609.04 (539.41 - 678.67)	3/Apr	1268.38 (893.82 - 1642.94)	661.90 (548.30 - 775.49)
5/Mar	1147.81 (999.78 - 1295.85)	610.80 (539.27 - 682.34)	4/Apr	1271.99 (890.35 - 1653.62)	663.66 (548.89 - 778.43)
6/Mar	1152.74 (996.42 - 1309.05)	612.56 (539.18 - 685.95)	5/Apr	1275.57 (886.91 - 1664.23)	665.42 (549.48 - 781.35)
7/Mar	1157.58 (992.99 - 1322.17)	614.33 (539.13 - 689.52)	6/Apr	1279.13 (883.50 - 1674.76)	667.18 (550.09 - 784.27)
8/Mar	1162.36 (989.50 - 1335.21)	616.09 (539.13 - 693.05)	7/Apr	1282.67 (880.13 - 1685.21)	668.94 (550.72 - 787.17)
9/Mar	1167.06 (985.95 - 1348.17)	617.85 (539.17 - 696.53)	8/Apr	1286.19 (876.78 - 1695.60)	670.70 (551.35 - 790.06)
10/Mar	1171.69 (982.35 - 1361.04)	619.61 (539.24 - 699.98)	9/Apr	1289.69 (873.47 - 1705.91)	672.47 (551.99 - 792.94)
11/Mar	1176.26 (978.71 - 1373.82)	621.37 (539.35 - 703.40)	10/Apr	1293.17 (870.20 - 1716.15)	674.23 (552.64 - 795.82)
12/Mar	1180.77 (975.04 - 1386.51)	623.14 (539.49 - 706.78)	11/Apr	1296.64 (866.96 - 1726.32)	675.99 (553.30 - 798.68)
13/Mar	1185.22 (971.33 - 1399.11)	624.90 (539.66 - 710.13)	12/Apr	1300.08 (863.75 - 1736.42)	677.75 (553.98 - 801.53)
14/Mar	1189.61 (967.60 - 1411.62)	626.66 (539.86 - 713.46)	13/Apr	1303.51 (860.58 - 1746.45)	679.51 (554.66 - 804.37)
15/Mar	1193.95 (963.86 - 1424.03)	628.42 (540.09 - 716.75)	14/Apr	1306.93 (857.44 - 1756.42)	681.28 (555.35 - 807.20)
16/Mar	1198.23 (960.10 - 1436.36)	630.18 (540.35 - 720.02)	15/Apr	1310.33 (854.33 - 1766.32)	683.04 (556.05 - 810.03)

A higher value of actual doubling time for the daily new cases than the predicted values indicates that the pandemic not only stopped growing at an exponential rate but also slowed down more than anticipated in Bangladesh, considering the number of daily tests as fixed. While the pandemic is slowing down in its spread among the Bangladeshi population, a lower doubling time for deaths than the predicted values indicate towards an increased rate of case fatality from COVID-19 among existing cases [25]. The doubling time for the daily deaths kept increasing at a steady rate up until 15 July, 2020, but after that it remained almost the same up until 26 July, and then started increasing sharply, indicating an exponential increase in the number of deaths as well as case fatalities from COVID-19 during the middle of the month of July. While the ARIMA model was able to reliably predict the change in doubling time for new cases, it could not predict the doubling time for deaths very accurately for first 11 days of the prediction and this could be due to a multitude of different reasons. Late in case reporting, inability to identify the danger signs of the COVID-19 by the patients or the family

members, delay in hospitalization, insufficiency of required infrastructure necessary for proper management of COVID-19 at hospitals, and shortage of trained and skilled health care professional for infection management at every level of healthcare services could contribute to this pattern of COVID-19 case fatality in Bangladesh [30]. As a unique initiative, our evaluation of the doubling time of daily new COVID-19 confirmed cases and deaths observed increasing trends of epidemic doubling time of COVID-19 infection in Bangladesh.

The new cases and deaths have declined in Bangladesh since July 1, 2020. Overall, Bangladesh experienced a relatively milder effect of the pandemic compared to countries in Europe and North America [31]. Countries with similar economy and demographic profiles in South and South East Asia and Sub-Saharan African were mildly affected by the COVID-19 pandemic. One possible explanation is that the younger demographics helped dilute the impact of COVID-19 in Bangladesh, as this has been seen in many other Asian and Sub-Saharan African countries [32]. Bangladesh has a relatively younger population with a median age of 27.9 years [33]. Another explanation is T-cell mediated immunity acquired through previous human coronavirus infection that could cross react with previous human coronavirus infection [32]. People living in tropical climate experience infectious diseases throughout the year compared to winter surge in temperate countries. However, the exact reason for why some countries were mildly affected by COVID-19 pandemic is still unknown. After an initial surge of the epidemic in April–June, Bangladesh experienced relatively slower spread rate which is explained through our doubling time prediction.

One of the major limitations of this study is considering daily sample test as a constant. The doubling time is correlated on the number of samples tested and we assumed that the testing number would not change significantly. However, our study found a moderate correlation between daily sample test data and confirmed cases and deaths (Pearson correlation value between daily tests and cases was r=0.525, and between daily tests and deaths was r=0.474). Bangladesh admittedly has a severe shortage of testing kits, PPE, masks, and infrared thermometers. Moreover, the lack of diagnostic facilities particularly in sub-districts, limited number of the healthcare workers, and a lack of understanding in rural areas are the causes of limited sample testing [27]. From 8 March, 2020 to date, the government of Bangladesh is administering on average between 12 000 and 15 000 tests per day for a population of 168 million [34]. Furthermore, Bangladesh was affected by cyclone 'Amphan' on 20 and 21 May, 2020 [35] and experienced Eid festivals in the month of May. Along with occasional delayed reporting, backlog, communications gaps with hard to reach areas, it is possible that all of the data used in this analysis is not 100% accurate [36,37]. Further, the speed of disease transmission has been linked with adopted control measures, human behavior and emergence of new SARS-CoV-2 variants as seen in Europe and North America [38,39]. Thus, the change of control measures, and the emergence and spread of new variants which can change the dynamics of transmission within a short span of time might affect our estimation.

Conclusion

The median doubling time for new COVID-19 cases and deaths were 90.51 and 86.02 days respectively over the whole period. The lowest median value for doubling new COVID-19 cases was 2.00 days in March 2020 and that of deaths was 3.01 days in March, 2020. There is an increasing trend for doubling period for daily new cases and recorded deaths. However, the daily cases and deaths toll had a shorter doubling time in the month of October with a mean value of 185.63 and 184.43 days respectively. Our estimation was based on the number of daily samples tested in the first 11 months that averagely ranges interquartile range (IQR): 10261-14774.5. However, these doubling times would not be changed over the predicted period if the daily sample testing would not change suddenly. Bangladesh experienced a mild effect of the pandemic compared to countries in Europe and North America. While the exact reason why Bangladesh was mildly affected by COVID-19 pandemic is still unknown, our predicted doubling period explains the slow spread rate of the virus in the country.

Abbreviations

COVID-19 - Coronavirus disease; DT- Doubling Time; UCL- Upper Confidence Limit; LCL- Lower Confidence Limit; ARIMA - Autoregressive Integrated Moving Average; DGHS - Directorate General of Health Services, Bangladesh; IEDCR - Institute of Epidemiology, Disease Control and Research

Conflict of Interest

The authors have no competing interests to declare.

Author's contribution

MMR conceptualized, supervised, analysed and drafted the study. MFH analysed and drafted the study. SMA, EA, SM helped with the preparation and editing of the draft. GKP updated and edited the new drafted. NH helped in supervision, analysis and editing of the draft. All authors critically checked the manuscript and approved the version to be submitted.

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References

1. World Health Organization. Director-General's opening remarks at the media briefing on COVID-19 - 11 March 2020. *WHO Director General's speeches* 4 (2020).
2. The Johns Hopkins University School of Medicine. Coronavirus Resource Center USA: The Johns Hopkins University 2020. Available at: https://coronavirus.jhu.edu/map.html. (Accessed: 20th March 2021)
3. Verity R. *et al.* Estimates of the severity of coronavirus disease 2019: a model-based analysis. *Lancet Infect. Dis.* 2020; 2020; **20**: 669–677. DOI: https://doi.org/10.1016/S1473-3099(20)30243-7.
4. Ahammed T *et al.* Estimation of novel coronavirus (covid-19) reproduction number and case fatality rate: a systematic review and meta-analysis. *medRxiv*. 2020. DOI: 10.1101/2020.09.30.20204644.
5. Rahman MM *et al.* Prevalence and Integration of symptoms and comorbidities with age of the SARS-CoV-2 patients: a systematic evaluation and meta-analysis. *medRxiv*. 2020. DOI:10.1101/2020.08.19.20177980.
6. Li Q *et al.* Early Transmission Dynamics in Wuhan, China, of Novel Coronavirus–Infected Pneumonia. *N. Engl. J. Med.* 2020; **382**: 1199–1207. DOI: 10.1056/NEJMoa2001316.
7. Siam MHB *et al.* Insights into the first wave of the COVID-19 pandemic in Bangladesh: Lessons learned from a high-risk country. *medRxiv*. 2020. DOI: 10.1101/2020.08.05.20168674.
8. World Health Organization. *CO V I D -19 STRATEGY UP DATE*. 2020. (Accessed: 20th March 2021).
9. Zhang Z. Corrigendum to a novel covid-19 mathematical model with fractional derivatives: Singular and nonsingular kernels. *Chaos, Solitons & Fractals. 2020;* **140**: 110128. DOI: 10.1016/j.chaos.2020.110128.
10. Păcurar CM & Necula BR. An analysis of COVID-19 spread based on fractal interpolation and fractal dimension. *Chaos, Solitons & Fractals*. 2020; **139**: 110073. DOI: https://doi.org/10.1016/j.chaos.2020.110073.
11. Soukhovolsky V, Kovalev A, Pitt A & Kessel B. A new modelling of the COVID 19 pandemic. *Chaos, Solitons & Fractals*. 2020; **139**: 110039. DOI: https://doi.org/10.1016/j.chaos.2020.110039.
12. Torrealba-Rodriguez O, Conde-Gutiérrez RA & Hernández-Javier AL. Modeling and prediction of COVID-19 in Mexico applying mathematical and computational models. *Chaos, Solitons & Fractals*. 2020; **138**: 109946. DOI: https://doi.org/10.1016/j.chaos.2020.109946.
13. Patel SB & Patel P. Doubling Time and its Interpretation for COVID 19 Cases. *Natl. J. Community Med.* 2020; **11**: 141–143.
14. Muniz-Rodriguez K *et al.* Doubling Time of the COVID-19 Epidemic by Province, China. *Emerg. Infect. Dis. J.* 2020; **26(8)**: 1912.
15. Xu S, Clarke C, Shetterly S, Narwaney K. Estimating the Growth Rate and Doubling Time for Short-Term Prediction and Monitoring Trend During the COVID-19 Pandemic with a SAS Macro. J Emerg Rare Dis. 2020; 3(1):121.
16. Patel, S. B. *et al.* Estimating the Growth Rate and Doubling Time for Short-Term Prediction and Monitoring Trend During the COVID-19 Pandemic with a SAS Macro. *medRxiv Prepr. Serv. Heal. Sci.* **11**, 141–143 (2020).
17. World Health Organization. WHO Coronavirus Disease (COVID-19) Dashboard: Bangladesh. (2020). Available at: https://covid19.who.int/region/searo/country/bd. (Accessed: 19th March 2021).
18. Shammi M, Bodrud-Doza M, Islam ARMT & Rahman, M. M. Strategic assessment of COVID-19 pandemic in Bangladesh: comparative lockdown scenario analysis, public perception, and management for sustainability. *Environ. Dev. Sustain.* 2020; 1–44. DOI:10.1007/s10668-020-00867-y.
19. Ahmed A & Rahman MM. COVID-19 trend in Bangladesh: deviation from epidemiological model and critical analysis of the possible factors. *medRxiv*. 2020. DOI: 10.1101/2020.05.31.20118745.
20. Ministry of Health and Family Welfare & Directorate of Health Studies. Bangladesh Health Observatory. Available at: https://dghs.gov.bd/index.php/en/data. (Accessed: 28th September 2020)
21. Institute of Epidemiology Disease Control and Research. Coronavirus Disease 2019 (COVID-19) Information Bangladesh. Available at: https://corona.gov.bd/. (Accessed: 28th September 2020)
22. Roy S, Bhunia GS & Shit PK. Spatial prediction of COVID-19 epidemic using ARIMA techniques in India. *Model. Earth Syst. Environ.* 2020. DOI: https://doi.org/10.1007/s40808-020-00890-y.
23. Sharma VK & Nigam U. Modeling and Forecasting of COVID-19 Growth Curve in India. *Trans. Indian Natl. Acad. Eng.* 2020; **5**: 697–710. DOI: https://doi.org/10.1007/s41403-020-00165-z.
24. Paul J, Hoque MS & Rahman MM. Selection of Best ARIMA Model for Forecasting Average Daily Share Price Index of Pharmaceutical Companies in Bangladesh: A Case Study on Square Pharmaceutical Ltd. *Glob. J. Manag. Bus. Res.* 2013; **13**.
25. WHO. *WHO Bangladesh COVID-19 Morbidity and Mortality Weekly Update (MMWU)*. (2020).
26. Significance magazine. How exceptional a rugby

player was Brian O'Driscoll? Available at: https://www.significancemagazine.com/science/676-visualizing-the-covid-19-pandemic-with-doubling-rateshttps://wwwnc.cdc.gov/eid/article/26/8/20-0219_article. (Accessed: 10th October 2020)

27. Anwar S, Nasrullah M & Hosen MJ. COVID-19 and Bangladesh: Challenges and How to Address Them. *Front. public Heal.* 2020; **8**: 154. DOI: 10.3389/fpubh.2020.00154.
28. Kamruzzaman M & Sakib SN. Bangladesh imposes total lockdown over COVID-19. (2020). Available at: https://www.aa.com.tr/en/asia-pacific/bangladesh-imposes-total-lockdown-over-covid-19/1778272#. (Accessed: 10th October 2020).
29. International Monetary Fund. Policy Responses to COVID-19. (2020). Available at: https://www.imf.org/en/Topics/imf-and-covid19/Policy-Responses-to-COVID-19. (Accessed: 10th October 2020).
30. Huq S & Biswas RK. COVID-19 in Bangladesh: Data deficiency to delayed decision. *J. Glob. Health* 2020; **10 (1)**: 10342. DOI: 0.7189/jogh.10.010342.
31. Haider N *et al.* The Global Health Security index and Joint External Evaluation score for health preparedness are not correlated with countries' COVID-19 detection response time and mortality outcome. *Epidemiol. Infect.* 2020; **148**: e210. DOI: 10.1017/S0950268820002046.
32. Mukherjee S. Why Does the Pandemic Seem to Be Hitting Some Countries Harder Than Others? *The New Yorker* 2021. Available at: https://www.newyorker.com/magazine/2021/03/01/why-does-the-pandemic-seem-to-be-hitting-some-countries-harder-than-others. (Accessed: 3rd March 2021)
33. Index Mundi. Bangladesh Demographics Profile. *2020* Available at: https://www.indexmundi.com/bangladesh/demographics_profile.html. (Accessed: 20th March 2021)
34. Cousins S. *Bangladesh ' s COVID-19 testing criticised. The Lancet.* 2020; 396(10251): P591. DOI:https://doi.org/10.1016/S0140-6736(20)31819-5.
35. OCHA. Bangladesh Cyclone Amphan Joint Needs Assessment. (2020).
36. Xinhua. Bangladesh Muslims celebrate Eid-ul-Fitr amid COVID-19. *2020* Available at: http://www.xinhuanet.com/english/2020-05/25/c_139086370.htm. (Accessed: 10th October 2020)
37. Kamruzzaman M. Eid preparation horde may worsen pandemic in Bangladesh. (2020). Available at: https://www.aa.com.tr/en/asia-pacific/eid-preparation-horde-may-worsen-pandemic-in-bangladesh/1851461. (Accessed: 10th October 2020)
38. Davies NG *et al.* Estimated transmissibility and impact of SARS-CoV-2 lineage B.1.1.7 in England. *Science. 2021; 80*: e3055. DOI:10.1126/science.abg3055
39. Huang J & Qi G. Effects of control measures on the dynamics of COVID-19 and double-peak behavior in Spain. *Nonlinear Dyn.* 2020; **101**: 1889–1899. DOI: https://doi.org/10.1007/s11071-020-05901-2.

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