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Research article

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Change Point Modeling of COVID-19 Transmission in Bangladesh

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Abstract

Background: *COVID-19 pandemic is recognized as a significant threat to human health in 2020 in Bangladesh. Without emergence of effective medicine and vaccine it is very difficult to control the transmission of the COVID-19. Thus, identifying and monitoring the trajectory in the COVID-19 pandemic continuously is very important to assess the action taken to contain this pandemic and to have a further decision.*

Methods and Material: *In this context, this study tries to find out the trend of daily reported confirmed cases of COVID-19 in Bangladesh. The 174 days' daily data have been taken from the website of worldometer Bangladesh from 10 March to 30 August, 2020 for the analysis. To analyze the trends and to identify significant changes in trends joinpoint regression analysis has been used.*

Results: *The number of cases increased by the rate of 4.98 percent per day in Bangladesh, however, from 11th June to 30th August i.e. for 81 days, the growth rate is found negative means we observed a decline in the COVID-19 cases per day with the rate of -0.6 percent.*

Conclusions: *Evidence suggests that there is an impact of lockdown that slow down the spread of COVID-19 daily cases in Bangladesh.*

Keywords: COVID-19 Pandemic, Jointpoint Regression, Average Daily Percent Change, Bayesian Information Criterion.

Introduction

A new virus introduced in December 2019, called the severe acute respiratory syndrome corona virus 2 (SARS-CoV-2) caused a disease outbreak in China [1]. It was first discovered in the city of Wuhan, the provincial capital of Hupei province in central China, in the middle of December 27th. This virus can remain dormant for 2 to 7 days after being infected in the body and can be infected with another person's body during this time [2]. COVID-19 pandemic has challenged resource allocation and management system, especially in public health domain in Bangladesh as well as the health professionals is threatened by the super-spreading behavior of novel corona virus due to risk of infection. From the beginning government declared "lockdown" throughout the nation in order to protect the population on 23 March when the confirmed cases were 33. The nation-wide lockdown continued up to 30 May and prepared some necessary steps to spread awareness to keep this syndrome away from them. On 6 April 2020, more than 100 confirmed cases of COVID-19 were reported which increased to 500 by 12 April 2020 and crossed over 1000 on 14 April 2020 (doubled within 2 days). Since then, the number of daily reported confirmed cases increased sharply and it passed the 10000 mark by 5 May 2020 and the 50000 mark by 2 June 2020.

WHO's and many other researchers advised that COVID-19 disease is currently a significant threat to developing and poor country [3-6]. In a study, Imperial College of London model, a projection report says that in Bangladesh, the Corona pandemic can be infected with a total of eight million [7]. In addition, BRAC's research model, projects that Corona virus can kill 5 million people in Bangladesh [8]. Without inventing vaccination or proper treatment, how we control the transmission of the COVID-19 is one of the most admitted questions with that people are facing right now. Until such treatments are developed, some policies termed as isolation, quarantine, lockdown, and social distancing would give a stunning direction to control the epidemic outbreak [9].

The advancement of COVID-19 presents a challenge for data scientists to model it as the epidemiological characteristics of the disease are yet to be fully explained. No treatments for COVID-19 and no vaccine, at present are available to protect from

novel corona virus. The uncertainty regarding the advancement of COVID-19 pandemic therefore creates additional pressure on the epidemiologists and public health experts on how to control it. In such circumstances, the forecasting COVID-19 case is very important for planning and implementing infection containment and pandemic control measures. The trend analysis of daily reported confirmed cases of COVID-19 is essential due to the declaration of the nation-wide lockdown in Bangladesh on 23 March 2020 has significantly decelerated the progress of COVID-19 pandemic in the country. It has even been argued that re-imposing the harsh restrictions as part of the lockdown across the nation is only way of stopping or decelerating the progress of COVID-19 pandemic in spite of the fact that the socio-economic cost of lockdown across the nation that is quite complex and exorbitant. It has repeatedly been stressed that because of serious social and economic implications of the nation-wide lockdown, it cannot be prolonged.

A review of the daily reporting of the confirmed COVID-19 cases in Bangladesh shows that up to 13 March 2020, only 3 confirmed cases were found. However, during the period 14 March 2020 through 14 April 2020, the daily reported confirmed cases were highly inconsistent. For analysis purpose, the irregular fluctuations in daily reporting of confirmed cases of COVID-19 resulting from the inconsistencies in reporting are to be removed before any analysis of the trend in the reported confirmed cases of COVID-19. Moving average is an approach to reduce the impact of observing inconsistency in the analysis of the trend in daily reporting cases of confirmed COVID-19 instead of actual daily reported confirmed cases of COVID-19. Such approach has been applied in this study for proper analysis. To minimize the effect of irregular fluctuations in the reporting of COVID-19 cases in the trend analysis, five-day moving average has been used instead of daily reported confirmed cases of COVID-19.

Tracing and monitoring continuously the trajectory of the COVID-19 pandemic are very important to assess for the action taken to contain this pandemic and to have a further decision. We provide the trends and significant changes in the coronavirus disease 2019 (COVID-19) outbreak in Bangladesh for about 150 days, from 08 March to 06 August, 2020. Since the daily data in Bangladesh is more or less inconsistent thus 5 days moving average is used to smooth the data. Therefore, in fact from 10 March to 04 August, 2020 is used for analysis. These daily data have been taken from the website worldometer (2020) Bangladesh. For the analysis, we used the number of confirmed COVID-19 cases data posted in the official website of the worldometer data for Bangladesh. To analyze the temporal trends and to identify important changes in the trends of the COVID-19 outbreak joinpoint regression is used in China and in India; here in this study we performed a joinpoint regression analysis in Bangladesh to understand the pattern of COVID-19 [10, 11]. Joinpoint regression analysis, enable us to identify time at a meaningful change in the slope of a trend is observed over the study period. The best fitting points known as joinpoints, that are chosen when the slope changes significantly in the models.

A brief introduction of Joinpoint Regression Model

To tackle the above problem joinpoint regression analysis has been employed in this study to present trend analysis [12]. The goal of the joinpoint regression analysis is not only to provide the statistical model that best fits the time series data but also, the purpose is to provide that model which best summarizes the trend in the data [13].

Let y_i denotes the reported COVID-19 positive cases on day ti such that $t_1<t_2<...<t_n$. Then the joinpoint regression model is defined as

$$\ln y_i = \alpha + \beta_1 t_1 + \delta_1 u_1 + \delta_2 u_2 + ... + \delta_j u_j + \varepsilon_i \qquad (1)$$

where $$u_j = \begin{cases} (t_j - k_j) & if\ t_j > k_j \\ 0 & otherwise \end{cases}$$

and $k_1<k_2.....<k_j$ are joinpoints. The details of joinpoint regression analysis are given elsewhere (Kim et al., 2004).

Joinpoint regression analysis is used when the temporal trend of an amount, like incidence, prevalence and mortality is of interest [14, 15]. However, this method has generally been applied with the calendar year as the time scale [16-19]. The joinpoint regression analysis can also be applied in epidemiological studies in which the starting date can be easily established such as the day when the disease is detected for the first time as is the case in the present analysis [20]. Estimated regression coefficients (β) were calculated for the trends extracted from the joinpoint regression. Additionally, the average daily percent change (ADPC), calculated as a geometric weighted average of the daily percent changes [21]. The joinpints are selected based on the data-driven Bayesian Information Criterion (BIC) method [22].

The equation for computing the BIC for a *k-j*oinpoints regression is:

$$BIC(k) = \ln\left[\frac{SSE(k)}{n}\right] + \frac{2(k+1)\times \ln(n)}{n} \qquad (2)$$

Where SSE is the sum of squared errors of the k-joinpoints regression model and n is the number of observations. The model which has the minimum value of BIC(*k*) is selected as the final model. There are other methods also for identifying the joinpoints such as permutation test method and the weighted BIC methods. Relative merits and demerits of different methods of identifying the joinpoints are discussed elsewhere [23]. The permutation test method is regarded as the best method but it is computationally very intensive. It controls the error probability of selecting the wrong model at a certain level (i.e. 0.05). The BIC method, on the other hand, is less complex computationally.

In the present case, data on the reported confirmed cases of COVID-19 are available on a daily, thus the daily percent change (*DPC*) from day t to day (t+1) is defined as

$$DPC = \left(\frac{y_{t+1} - y_t}{y_t}\right) \times 100 \qquad (3)$$

If the trend in the daily reported confirmed cases of COVID-19 is modeled as

$$\ln(y_t) = b_0 + b_1 t + \varepsilon \qquad (4)$$

then, it can be shown that the *DPC* is equal to

$$DPC = (e^{b_1} - 1) \times 100 \quad (5)$$

It is worthwhile to discuss here is that the positive value of DPC indicates an increasing trend while the negative value of DPC suggests a declining trend. The DPC reflects the trend in the reported COVID-19 positive cases in different time segments of the reference period observed through joinpoint regression techniques. For the entire study period, it is possible to estimate average daily percent change (ADPC) that is the weighted average of DPC of different time segments of the study period with weights equal to the length of different time segments. However, when the trend changes frequently, ADPC has little meaning.

Results

To observe the trend of reported cases, the moving average method has been used in this study. The daily per cent change (DPC) in the daily reported confirmed cases of COVID-19 during the period 10th March 2020 through 30th August 2020 is used for forecasting the daily reported confirmed cases of COVID-19 in the immediate future under the assumption that the trend in the daily reported confirmed cases of COVID-19 remains unchanged (Table 1). The number of cases increased by the rate of 4.98 percent per day in Bangladesh; however, the rate is different in the different segment. Also Table 1 reveals that the growth rate is positive and significant (about 20 percent) from 10th March to 23rd March but after that the growth rate is negative i.e. decreasing for 8 days (from 23rd March to 30th March). The possible reason may be less reporting during the first week of imposing lockdown in Bangladesh (from 23rd March to 30th May). In the third segment i.e. from 30th March to 6th April very high and statistically significant increase has been observed in Bangladesh, perhaps the accumulated cases in the previous week comes in cluster. From 6th April to 16th April the rate is although the positive but dramatically lower than the previous segments growth rate. In the next segment i.e. 5th segment which is much large of 57 days, we observe a very low increase in COVID-19 cases. In the last and 6th segment from 11th June to 30th August i.e. for 81 days, the growth rate is found negative means we observed a decline in the COVID-19 cases per day. It is only -0.6 percent and statistically significant. This gradual decrease in DPC may be the result due to lockdown. Figure 1 shows that the trend increases sharply and it has a tendency to start declining from the mid June. Since 10th March, the daily COVID-19 cases have been increasing at a various rate in Bangladesh (Figure 1) and since 11th June the cases decreased by almost 0.6 percent per day. Figure 2 shows the forecasted value of COVID-19 daily Cases in Bangladesh. The corona virus cases will decrease further if the same trend prevailing, if people strictly follow the health rules such as use mask as well as social distancing and government observe the odds situation against corona virus. Then the effect of increasing corona virus cases will be controlled automatically.

Table 2 presents the forecast of the predicted cases of COVID-19 in Bangladesh along with 95 percent confidence intervals. This exercise suggests that by 30th September 2020, the daily reported confirmed cases of COVID-19 in Bangladesh is likely to be 1872 with a 95 per cent confidence interval of 1797-1949. This daily reported COVID-19 positive cases may change only when an appropriate set of new interventions are introduced to fight COVID-19 pandemic. The forecast of the daily reported COVID-19 positive cases, on the basis of the joinpoint regression analysis also suggests that the total number of COVID-19 positive cases in the country is likely to increase to almost 372546 by the end of September 2020 with a 95 per cent confidence interval ranging from around 371346 to around 373776 if the present trend in the daily reported confirmed cases of COVID-19 continues in the days to come. This implies that the daily reported confirmed cases of COVID-19 in the country are bound to decrease quite satisfactorily in the days to come. This forecast about the decrease in the reported confirmed cases of COVID-19 in the country comes possibly due to the introduction of appropriate interventions.

Conclusions

This study is based on the daily reported confirmed cases of COVID-19, asserts that there has virtually been moderate impact of the nation-wide lockdown as well as relaxations in restrictions on the progress of the COVID-19 pandemic in Bangladesh. This conclusion is based on the hypothesis that if the nation-wide lockdown has been effective, the trend in the reported confirmed cases of COVID-19 in the country would have changed statistically significantly. A study in Bangladesh COVID-19 spread shows that the peak (about 3000 per day) will come in July and after that decline in COVID-19 case has been observed; also findings of this study are more or less similar to the findings of study [24-26]. It is suggested that in Bangladesh the progress of the COVID-19 epidemic in regional level of the country differ from one to another region such as one division to another division as well as one district to another. To know the better understanding of the progress of the epidemic in the country may be obtained by analyzing the progress of the epidemic at the regional level. It is worthwhile to mention that joinpoint regression analysis does such an important task which is a very time intensive process.

Table 1: Results of the Joinpoint Regression Analysis, Bangladesh

Segment	Lower Endpoint	Upper Endpoint	Number of Days$	Daily Percent Change (DPC)	95 percent confidence interval		Test Statistic (t)	p>|t|
					Lower	Upper		
1	10-03-20	23-03-20	14	19.97*	17.62	22.36	18.21	0.00
2	23-03-20	30-03-20	8	-20.88*	-25.85	-15.57	-7.12	0.00
3	30-03-20	06-04-20	8	68.03*	57.47	79.3	15.79	0.00
4	06-04-20	16-04-20	11	22.89*	18.68	27.25	11.69	0.00
5	16-04-20	11-06-20	57	4.51*	4.27	4.75	38.64	0.00
6	11-06-20	30-08-20	81	-0.60*	-0.73	-0.47	-9.25	0.00
All	**10-03-20**	**30-08-20**	**174**	**4.98***	**4.51**	**5.46**	**20.98**	**0.00**

*Statistically significant. # Average daily per cent change (ADPC), $Number of days in a segment include both lower endpoint and upper endpoint.

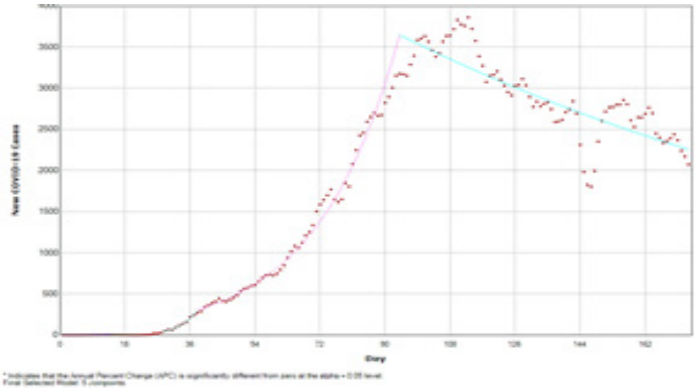

Figure 1: Trend in daily reported COVID-19 in Bangladesh using joinpoint regression analysis with BIC criterion

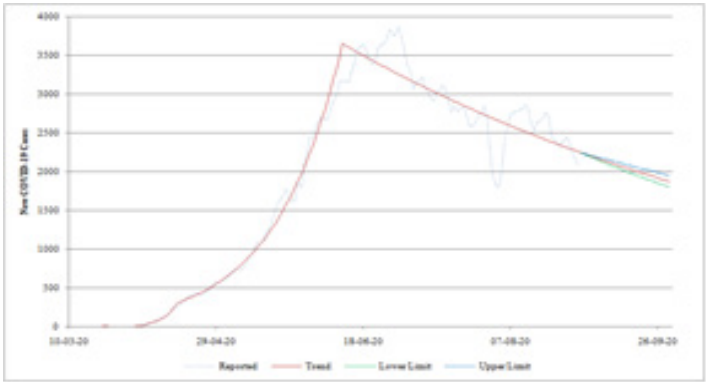

Figure 2: Forecast of daily reported COVID-19 cases in Bangladesh up to 30th September 2020

Table 2: Forecast of Daily Predicted COVID-19 Cases till 30th September 2020, Bangladesh

Date	Predicted	95 percent Confidence limit		Date	Predicted	95 percent Confidence limit	
		Lower	Upper			Lower	Upper
01-09-20	2229	2223	2234	16-09-20	2036	1991	2082
02-09-20	2215	2207	2224	17-09-20	2024	1977	2072
03-09-20	2202	2190	2213	18-09-20	2012	1962	2062
04-09-20	2189	2174	2203	19-09-20	2000	1948	2053
05-09-20	2176	2159	2193	20-09-20	1988	1934	2043
06-09-20	2163	2143	2182	21-09-20	1976	1920	2034
07-09-20	2150	2127	2172	22-09-20	1964	1906	2024
08-09-20	2137	2112	2162	23-09-20	1952	1892	2014
09-09-20	2124	2096	2152	24-09-20	1941	1878	2005
10-09-20	2111	2081	2142	25-09-20	1929	1864	1996
11-09-20	2098	2066	2132	26-09-20	1917	1851	1986
12-09-20	2086	2051	2122	27-09-20	1906	1837	1977
13-09-20	2073	2036	2112	28-09-20	1894	1824	1968
14-09-20	2061	2021	2102	29-09-20	1883	1810	1958
15-09-20	2049	2006	2092	30-09-20	1872	1797	1949

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