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Assessing the Impact of Complete Lockdown on COVID-19 Infections in India and its Burden on Public Health Facilities

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Abstract: In this paper, an attempt has been made to assess the impact of complete lockdown on COVID-19 infection in India. This study obtained COVID-19 data on daily confirmed, recovered, and deaths for 21 days and have implemented the exponential growth model to predict future cases and study the role of lockdown in reducing the number of confirmed COVID 19 cases and deaths. The mathematical model was used to calculate the average reproduction number and herd immunity. Initially, the curve of confirmed cases and deaths grows exponentially; but later, the government-enforced lockdown has helped in curtailing the growth of the curve. The preventive measures may have averted around 4,31,915 confirmed cases and 32,856 deaths till May 3, 2020. The reproduction rate was estimated at 2.56 during the pre-lockdown period and is reduced to 1.56 during lockdown period. It is also observed that the number of COVID-19 patients in a government hospital in India as on May 3 would have been on an average of 15 cases per hospital if it grows exponentially. However, due to lockdown, it has reduced to the level of 2 cases per hospital. The number of confirmed cases grew around 19 percent during the pre-lockdown period of March 14-24, 2020, and stabilizes at the same pace till April 5. Post-April 5, the decline in the growth rate of confirmed cases reached as low as 10 percent. Results indicate that the preventive measures taken at the early stages have successfully helped in preventing a large number of deaths and infected cases in India.

Keywords: COVID-19, India, Lockdown, Reproduction number, Public health capacity.

Introduction

Towards the end of 2019, the outbreak of pneumonia cases of unknown etiology (unknown cause) occurred initially in Wuhan city capital of the Hubei province of China. As per the WHO's first situation reports on coronavirus disease 2019, from December 31, 2019 through January 3 2020, a total of 44 case-patients with such pneumonia were reported, and most of these cases were commonly exposed to the Huanan wholesale seafood market (World Health Organization [WHO], 2020a; Wang *et al*., 2020). China reported the outbreak to the World Health Organization on January 7, 2020 that new type of virus was identified as a coronavirus (2019-nCoV) (Corman *et al*., 2020). It is a zoonotic coronavirus which is similar to SARS and MERS coronavirus (Liu *et al*., 2020). Soon confirmed cases of COVID-19 were exported

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through Wuhan city initially in Thailand, Japan, South Korea, rapidly spreading to Europe, United States of America (USA), and have now spread to over more than 200 countries. With the alarming levels of spread and severity, WHO declared the outbreak of COVID-19 as Pandemic on 11thMarch 2020 (WHO, 2020b).

The severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or the novel coronavirus (COVID-19) has already taken on pandemic proportions. According to World Health Organization, on April 23 2020, there are 213 countries, areas or territories with around 2.6 million confirmed cases, and 0.18 million deaths due to COVID-19 (WHO, 2020c). The WHO Director-General in a media briefing stated that if nations can detect, test, treat, isolate, trace, and mobilize their people in the response, the countries with less number of cases can prevent these cases becoming clusters and growing those clusters into community transmission (WHO, 2020d).In much of the world, people exhibiting mild or no symptoms are unable to get tested, meaning that the actual number of cases could be much higher (Nature, 2020).The new public health crises emerging from COVID-19 have not only threatened the medical and public health infrastructure but also the economy of countries across the globe. In the past few weeks, countries such as Italy, Spain, and the USA have been devastated by COVID-19 as there was massive increase in the number of cases and deaths per day (John Hopkins, 2020).Even after the gradual increase in facilities, the situation in these countries remains alarming (Narain, 2016). The new contagious disease of coronavirus (COVID-19) with no available vaccine is likely to be a threat to India's health care systems if appropriate steps are not contemplated. India being the second-most populous country of the world with high population density might be at a higher risk of the sudden outbreak as COVID-19 has very high human to human transmissibility. Developing a vaccine for COVID-19 has emerged as a new challenge for medical scientists and researchers, which might need more time. In this context, only feasible precautionary measures that come to the forefront are the early detection of symptomatic as well as asymptomatic cases, social distancing and isolating confirmed cases to check further transmission of the disease. India had the potential to become a hotspot, but India's pre-emptive strategy and advance precautionary measures have curbed the spread of COVID-19 to a large extent. India had started screening of international passengers even before the first case detected in the country (Press Information Bureau [PIB], 2020a). The Government of India has taken many prudent and proactive measures such as early screening, mass media campaigns for preventive measures, national lockdown, travel restrictions, and quarantine, which have directly and indirectly controlled mass spread of COVID-19.

In India, the first positive case of the COVID-19 was detected on January 30 2020 in Kerala (PIB, 2020b).In the beginning, the numbers remain nearly constant until early March but since then, the outbreak spread rapidly in almost all parts of the country. As of April 23 2020, there are 17,306 active cases of COVID-19, and 721 deaths have been reported from 32 states/UTs as per the Ministry of Health and Family Welfare, GOI. A majority of the patients initially identified with an international traveling history. These cases worked as primary agents of transmission of the virus. Hence, it is important to estimate the transmission dynamics in the initial days of the outbreak of disease and predictions about the potential growth of cases (Viboud *et al.*, 2018). This prediction can provide insights into the epidemiology of the disease, which will help policymakers to check health systems capacities. It can identify whether the control measures are having a measurable effect or not (Funk *et al.*, 2017; Riley *et al.*, 2003) and

also, a prediction model can be updated to estimate the risk of the disease in the near future (Cooper *et al.*, 2006).

The transmissibility of COVID-19 from human to human is sufficient to support sustained transmission unless specific control measures are implemented (Natsuko *et al.*, 2020).In India, complete lockdown of 21 days was announced by the Ministry of Home Affairs order dated March 24 2020, which was further extended till May 3 2020 (PIB, 2020c; PIB, 2020d). Therefore, it becomes imperative to study the effect of current measures to combat coronavirus (COVID-19). Another objective of this study is to ascertain the effects of lockdown and other precautionary measures in reducing the number of confirmed cases and deaths due to COVID-19. An attempt has also been made to estimate the burden on public health systems.

Data and Methodology

Data on COVID-19 was taken from the data-sharing portal covid19india.org, which provides nearly the same figures published by government sources. We have collected information on three main components of interest, i.e., daily confirmed cases, daily recovered cases and daily deaths from March 14 to April 3, 2020 for a period of total 21 days for predicting the exponential growth in the number of cases. We emphasized on the active cases of COVID-19, which has been adjusted by recoveries and deaths. We have also calculated the cumulative number of cases for all the three components presented in Figure 1. Data on confirmed cases and deaths have also been collected from April 4 to May 3, 2020 to evaluate the impact of lockdown in reducing the number of confirmed cases and deaths.

Exponential Growth model

Since we have data on cumulative confirmed cases, recovered cases, and deaths for each day for 21 days, it is possible to fit an exponential growth model for these three data patterns. The basic exponential growth model is described as

$$\boldsymbol{N(t) = \alpha * exp(rt)} \quad \text{..... (1)}$$

Where **N(t)** = number of cases at any time 't.'

$\boldsymbol{\alpha}$ = constant; **r** = growth rate; and **t** = time (in days)

This growth model was adopted for all three components, and the prediction was made on the future cases until May 3, 2020. All these three components closely followed exponential growth with a rise in the number of confirmed cases more steadily compared to recovered cases and deaths. The exponential growth rate model for confirmed cases (C), recovered cases (R), and deaths (D) are based on the available data and is described in equations 2, 3, and 4, respectively. The active cases were calculated by subtracting the total recoveries and deaths from total confirmed cases described in equation 5. The active cases refer to the cases that will be active at that time and may require hospitalization and ICU (intensive care unit) in case of severe cases.

$$\boldsymbol{C}(t) = 79.84exp(0.1714 * t) \quad \text{.....(2)}$$

$$\boldsymbol{R}(t) = 7.3469exp(0.1609 * t) \quad \text{..... (3)}$$

$$\boldsymbol{D}(t) = 1.1697exp(0.2017 * t) \quad \text{..... (4)}$$

$$\boldsymbol{Active\ Cases}(t) = [\boldsymbol{C}(t) - \boldsymbol{R}(t) - \boldsymbol{D}(t)] \quad \text{.....(5)}$$

The total number of cases obtained from the above growth models is consistent with the cases observed from the data used, which can be reflected in Figures 1A, 1B, and 1C. Hence these growth models can provide us with fairly enough estimates which can be useful for the policymakers to be prepared for any such public health requirements for hospitalizations, ICU, and medical logistics like personal protection equipment (PPE), etc. The differences were calculated for the number of confirmed cases and deaths based on the cases predicted by exponential growth and actual observed cases from April 4 to May 3, 2020.

Mathematical Model for Reproduction Number and Herd Immunity

The mathematical model for calculating the number of incidence cases based on the reproduction number is defined as:

$$\mathbf{I}(\boldsymbol{t}) = (\boldsymbol{Ro})^{\boldsymbol{t/SI}} \quad \text{…….(6)}$$

I(t) = Number of incidence cases at time t

Ro = Reproduction number; **SI** = Serial interval and **t** = Prediction time

The number of cumulative cases has been calculated based on this mathematical model until May 3 2020.

Estimation of Reproduction Number and Herd Immunity

The reproduction number is defined as the average number of new infections generated by one infected individual during the entire infectious period in a fully susceptible population. The basic reproduction number reflects the ability of the infection to spread in the infectious period under no control (Anderson et al., 1992).The approach used to estimate the basic reproduction number in this model is to calculate the average Ro based on the daily cumulative cases for 21 days described in equation 7. The herd immunity (HI) is estimated based on reproduction number by equation 8. The herd immunity indicates the resistance to the spread of an infectious disease within a population that results if a sufficiently high proportion of individuals are immune to the disease, primarily through vaccination.

$$\boldsymbol{Ro} = [\sum \boldsymbol{exp}\{\boldsymbol{logI}(\boldsymbol{t})/(\boldsymbol{t/SI})\}] \div \mathbf{21} \quad \text{…….(7)}$$

$$\boldsymbol{HI} = [\,\mathbf{1} - (\mathbf{1}/\boldsymbol{Ro})] * \mathbf{100} \quad \text{…….(8)}$$

Serial Interval is the time between the onset of a primary and secondary case. Due to the unavailability of detailed data on this parameter, we have used SI as 4.4 days as reported in previous studies (Zhao *et al*., 2020).

Public Health Capacities of India

To ensure India's public health care system preparedness against the novel coronavirus, we have collected information on different public health facilities available in India, including the number of hospitals and beds available. Information on government hospitals has been taken from Rural Health Statistics, Ministry of Health and Family Welfare Statistics Division, Government of India, 2018-19 and total number of beds as of January 2019 was extracted from the Open Government data source provided by the Ministry of Health and Family Welfare (Ministry of Health and Family Welfare [MoHFW], 2019). Government hospitals include primary health centers, community health centers, sub divisional hospitals, district hospitals and medical

colleges. To estimate the distribution of public health facilities among the population, we have used the projected population of India for the year 2020 (Report of the Technical Group on Population Projections) (National Health Mission [NHM], 2019).The total projected population of India for March, 2020 is 133,29,00,000. The burden on public health facilities due to COVID-19 is estimated by the total number of cases of COVID-19 per hospital that needs to accommodate if the number of cumulative cases is projected by the exponential growth model and mathematical model on Ro. The impact of lockdown was also evaluated in terms of reduction in the burden on public health facilities on the basis of the number of predicted cases and actual observed cases till April 23, 2020.

Results

Table 1 provides the predicted confirmed cases, recovered cases, and deaths for COVID-19 in India till May 3, 2020. If the increase in the number of cases continues to grow exponentially in upcoming days then the number of active cases will rise to 4, 13,467, the death toll to 34,319 and the number of recovered cases to 26,908 by May 3, 2020. If the exponential growth was true the confirmed cases would have been 50,000 and then 1,00,000 by April 20 and April 24, respectively. The exponential growth models fit very closely with the number of observed cases before lockdown period but currently India does not follow the exponential pattern and the projected figures are off the mark.

Figure 1(a): Daily cumulative confirmed cases of COVID-19 based on exponential growth model in India

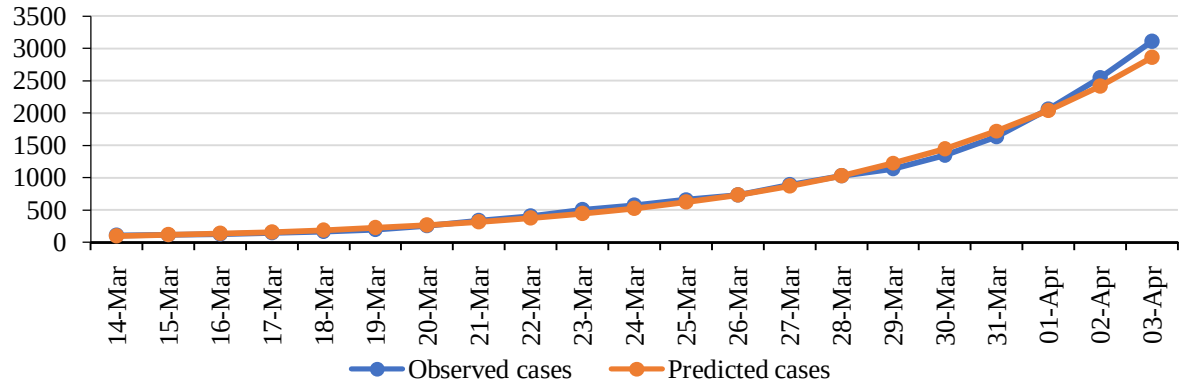


Figure 1(b): Daily cumulative recovered cases of COVID-19 based on exponential growth model in India

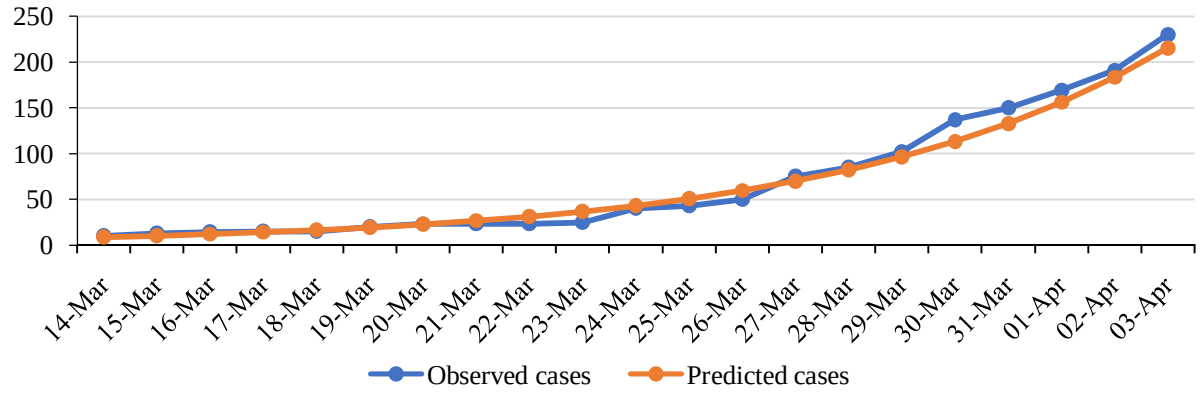


Figure 1(c): Daily cumulative deaths of COVID-19 based on exponential growth model in India

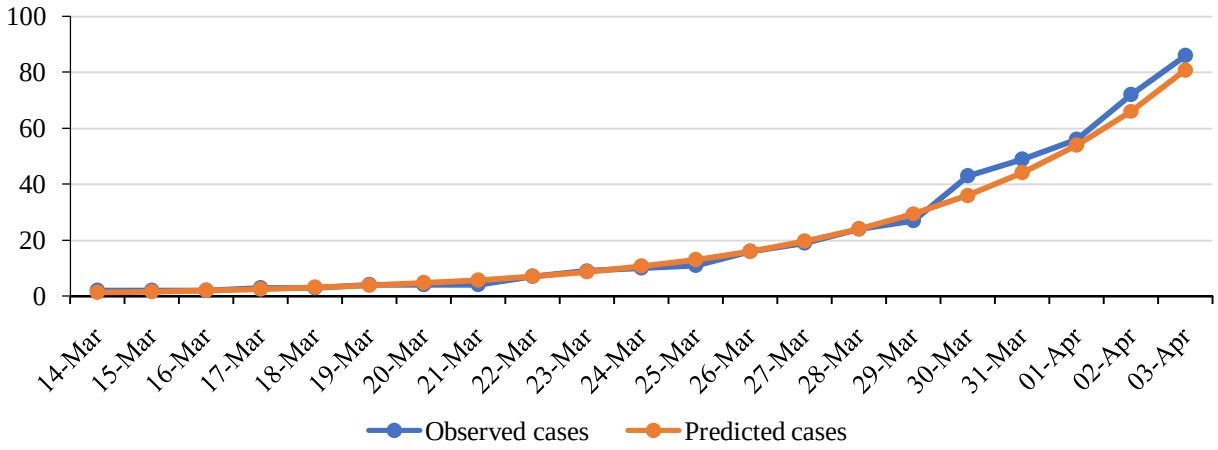
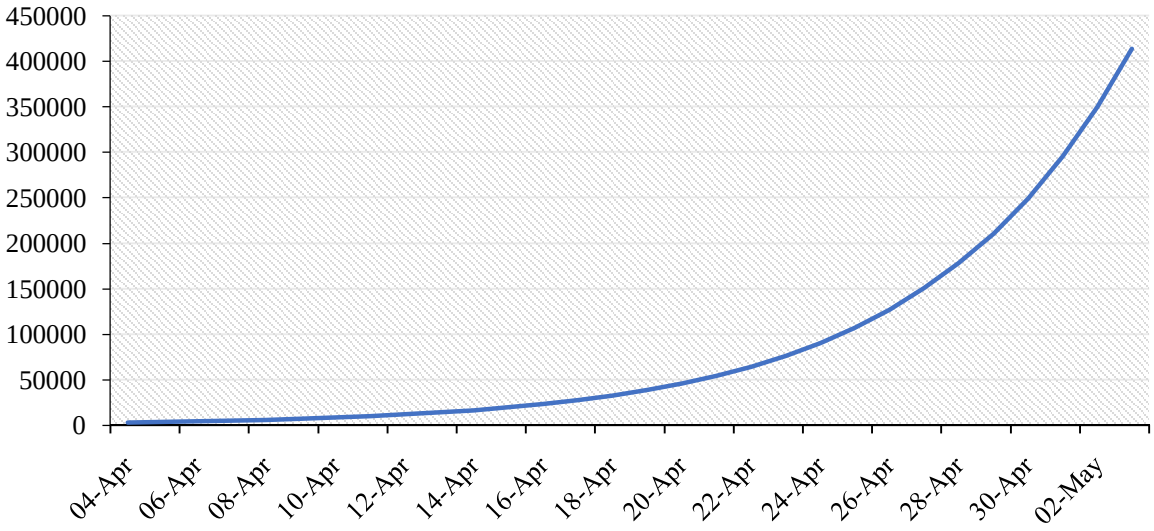


Table 1: Predictions for COVID-19 by exponential growth model until May 3, 2020 in India

Date	Confirmed Cases	Recovered cases	Deaths	Active cases
04-April	3391	253	99	3039
05-April	4021	297	121	3602
06-April	4768	349	148	4270
07-April	5653	410	181	5062
08-April	6704	482	222	6000
09-April	7949	566	271	7112
10-April	9426	665	332	8429
11-April	11177	781	406	9990
12-April	13254	917	497	11840
13-April	15716	1077	608	14031
14-April	18636	1265	743	16627
15-April	22098	1486	909	19702
16-April	26203	1746	1113	23345
17-April	31071	2050	1361	27659
18-April	36843	2408	1666	32769
19-April	43688	2829	2038	38821
20-April	51804	3323	2493	45988
21-April	61428	3903	3050	54475
22-April	72840	4584	3732	64524
23-April	86373	5384	4566	76422
24-April	102419	6324	5587	90508
25-April	121446	7428	6835	107183
26-April	144008	8724	8363	126921
27-April	170762	10247	10232	150283
28-April	202486	12036	12518	177931
29-April	240103	14137	15316	210650
30-April	284709	16605	18739	249365
01- May	337603	19504	22926	295172
02- May	400322	22909	28050	349363
03-May	474694	26908	34319	413467

Most countries have experienced exponential growth in COVID-19 cases, including China, USA, Italy, Spain, Germany, France. It took only 15 days in the USA to climb the number of confirmed cases from 1,000 to 1,00,000 as reported by the center for disease control and prevention (Centers for Disease Control and Prevention, 2020). The exponential phase may continue to increase until some serious preventive measures are taken (Figure 2).

Figure 2: Predicted active cases of COVID-19 based on an exponential growth model till May 3, 2020 in India



Deviations of Observed Cases from Predicted Cases based on Exponential Growth

The number of cases projected by the exponential growth model was compared to the actual observed cases until May 3. If the number of confirmed cases had grown exponentially, the cumulative cases on May 3 would have been 474694, but the observed confirmed cases on May 3 were 42779. The differences between the cases projected by exponential growth and actual observed cases are increasing with time, which is definitely a positive sign for India in terms of curtailing the exponential growth of COVID-19 cases in the country. Similarly, the number of total deaths due to COVID-19 till May 3 projected by exponential growth was 34319, which are 32856 more than the actual number of deaths reported. We also tried to analyze the differences in deaths by projecting the deaths by a logistic growth model as it will provide the gain at lower end. The difference in actual observed deaths and deaths projected by logistic growth until May 3 was 1064. These differences may be attributed to the complete lockdown in the country and other preventive measures adopted by India. These differences in cases and deaths are expected to expand in the coming days.

Table 2: Deviations of observed cases of COVID- 19 from the projected cases based on exponential growth rate in India till May 3, 2020

Date	Number of Confirmed Cases			Number of Deaths		
	Predicted Cases	Observed Cases	Differences	Predicted Deaths	Observed Deaths	Differences
04-Apr	3391	3684	-293	99	99	0
05-Apr	4021	4293	-272	121	121	0
06-Apr	4768	4778	-10	148	137	11
07-Apr	5653	5351	302	181	164	17
08-Apr	6704	5916	788	222	184	38
09-Apr	7949	6729	1220	271	230	41
10-Apr	9426	7600	1826	332	252	80
11-Apr	11177	8454	2723	406	292	114
12-Apr	13254	9212	4042	497	334	163
13-Apr	15716	10455	5261	608	361	247
14-Apr	18636	11490	7146	743	398	345
15-Apr	22098	12322	9776	909	423	486
16-Apr	26203	13432	12771	1113	451	662
17-Apr	31071	14352	16719	1361	489	872
18-Apr	36843	15722	21121	1666	524	1142
19-Apr	43688	17304	26384	2038	559	1479
20-Apr	51804	18543	33261	2493	592	1901
21-Apr	61428	20080	41348	3050	645	2405
22-Apr	72840	21372	51468	3732	681	3051
23-Apr	86373	23039	63334	4566	721	3845
24-Apr	102419	24448	77971	5587	781	4806
25-Apr	121446	26283	95163	6835	825	6010
26-Apr	144008	27890	116118	8363	881	7482
27-Apr	170762	29458	141304	10232	939	9293
28-Apr	202486	31360	171126	12518	1008	11510
29-Apr	240103	33065	207038	15316	1079	14237
30-Apr	284709	34867	249842	18739	1154	17585
01May	337603	37263	300340	22926	1231	21695
2-May	400322	39827	360495	28050	1323	26727
3-May	474694	42779	431915	34319	1463	32856

Figure 3(a): Differences in observed and predicted confirmed cases of COVID- 19 until May 3, 2020, India

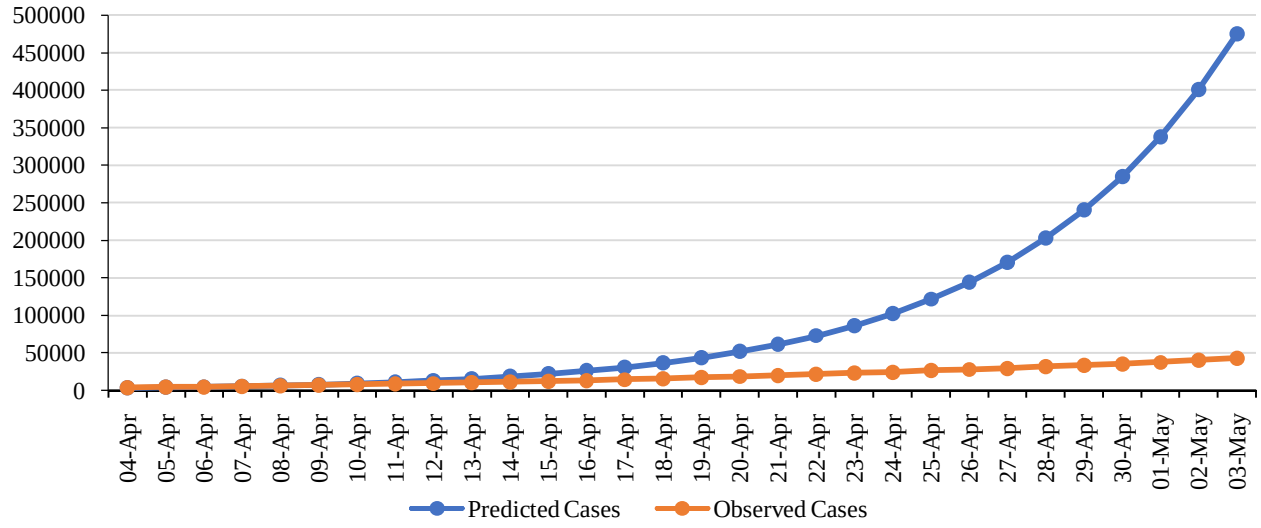
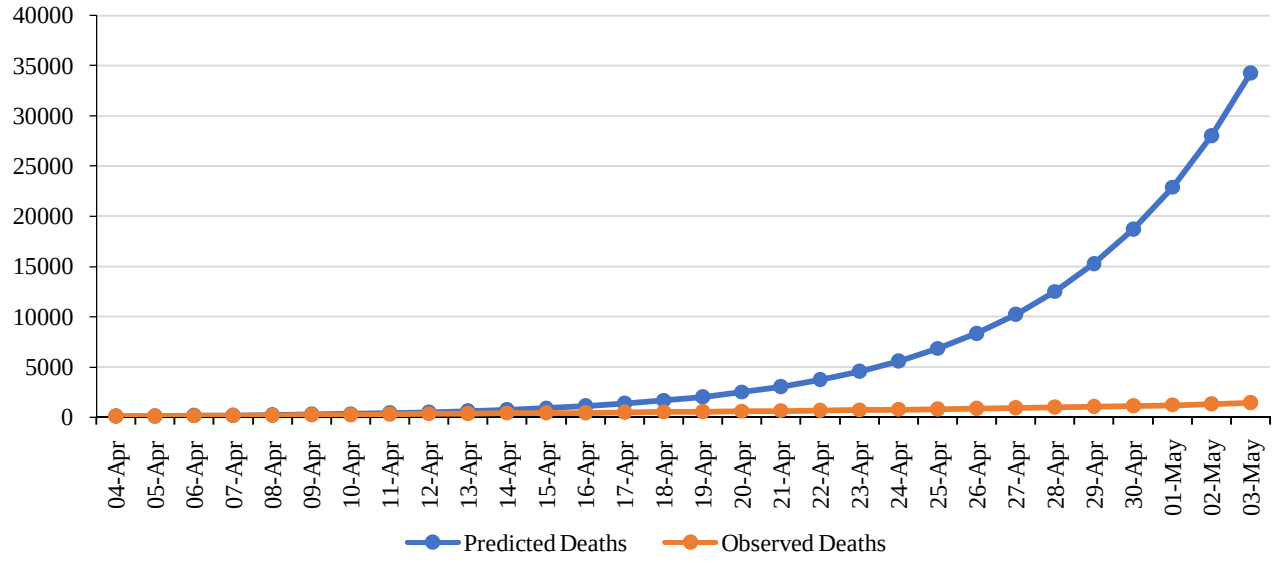


Figure 3(b): Differences in observed and predicted deaths of COVID- 19 until May 3, 2020, India



Reproduction Number

The reproduction number for India comes out to be 2.56 based on the reported cases in 21 days, which indicates one infected individual has infected, on average, 2.56 individuals in this period of 21 days. The reproduction number may decrease in the coming days for India due to the preventive measures taken by the government. The Herd Immunity for COVID-19 in India is estimated as 61%, indicating that if at least 61% of a susceptible population has immunization to COVID-19, it can result in the elimination of infection from the population. The number of cumulative cases if predicted by the mathematical model using the estimated reproduction number, comes out to be 2, 28,297 until May 3 2020 in the absence of any preventive measures. The main goal of lockdown is to keep reproduction below 1, that is, on average, with each case infecting fewer than one person. The value of reproduction number is around 1.56 during an effective lockdown period; it suggests that India has to go a long way to achieve the epidemiologically desirable result.

Public Health Facilities in India

The total number of government hospitals functioning in India is 23,582, and the total number of beds available in those hospitals is 7,10,761. If we consider the total population of India, the burden on public health facilities is quite high. A government hospital covers, on average, a total population of 47,631, and there is only one government hospital bed for the population of 1875. There will be, on average, 14.77 COVID-19 cases in one government hospital if the total number of cases continues to grow exponentially and, on average,8.15 COVID-19 cases if cases projected by the mathematical model are considered till May 3 2020. These results indicate that public hospitals should be prepared in terms of isolated wards, beds, ICUs, and other types of medical equipment. Further, it is also expected that around five percent of total cases need ICUs and this figure might go up if a large number of patients would become serious before getting hospitalized or tested for COVID-19.

Table 3: The Burden on Public Health Facilities in India due to COVID-19

Indicators	Number
Total number of Govt. Hospitals as on March 31, 2019*	27984
Total number of beds available as on January 31, 2019**	710761
Population coverage by one hospital*	47631
Population coverage by one bed in a hospital*	1875
No. of COVID-19 cases per Hospital until 3rdMay (projected by exponential growth model)	14.77
No. of COVID-19 cases per Hospital until May 3 (projected by mathematical model on Ro)	8.15
No. of COVID-19 cases per Hospital until May 3 (based on actual observed cases)	1.52

Source: *Rural Health Statistics, Ministry of Health and Family Welfare, Statistics Division, Govt. of India, 2018-19
**Ministry of Health and Family Welfare, Government of India, January 2019

It is also observed that the number of COVID-19 patients in a government hospital in India as on May 3 would have been on an average of 14.77 cases per hospital if it grows exponentially. However, due to lockdown, it has reduced to the level of 1.52 cases per hospital.

Discussions and Conclusions

The uncertainty around the novel coronavirus with no vaccine available until today sparks several concerns to the country's public health systems. This study presents the effect of several containment measures on the COVID-19 spread in India. It also assesses the public health preparedness based on the public health facilities available in the country. In case the exponential growth of COVID cases occurs, it may result in serious strain on the public health systems as in the case of several countries affected by COVID-19. India already has an overstretched public health care systems with a relatively low number of health functionaries. The density of physicians (7.8 per 10,000 population) and nurses (21.1 per 10,000 population) is low as compared to the world average (WHO, 2019). As compared to developed countries with a nurse-to-physician ratio of 3:1, India's ratio stands at around 0.6:1. This becomes a matter of utmost concern as the majority of the facilities are concentrated in the urban areas catering to only 30% of India's population (Hazarika, 2013).

The differences existing in the exponential growth rate and the observed cases show that India has already taken pivotal preventive measures to control the spread of the disease**.** Due to the dearth of testing kits, there is some concern about the capacity of screening COVID-19 positive cases in the country. Consequently, the number of confirmed cases may not represent the complete prevalence of COVID cases in India. Initially, India has adopted a strategic testing approach, where symptomatic individuals under certain criteria and asymptomatic individuals in contact with COVID-19 positive patients were tested. As per the reports from the Indian Council of Medical Research (ICMR) of as of April 24 2020,a total of 5,41,789 samples have been tested, suggesting a much lower rate of testing as compared to other countries. Moreover, as the number of COVID-19 cases rising rapidly in India, the health research department of ICMR has also encouraged the state governments to opt for pooled sampling for PCR screening of multiple individual patient specimens, followed by individual testing which will increase the coverage of testing for the purpose of surveillance. However, pooled sampling is only preferable in the areas of low positive rates of 2-5% of COVID-19 and sample should not exceed five individuals (MoHFW, 2020a). As the number of operational Government laboratories has been increasing to

diagnose the COVID-19 in India, it is expected that the screening will increase in the upcoming days, which will subsequently raise the testing capacity of the country.

The Indian government has taken many preventive measures for containment of COVID 19 at the early stage of infection. It included complete lockdown for initially for three weeks which was extended again for another 18 days, measures to ensure social distancing, case isolation, geographical quarantine which calls for near-absolute interruption of movement of people to and from areas of the single large outbreak or multiple foci of local transmission of COVID-19 and national and international travel restrictions etc. Under the geographical quarantine in hotspot marked zones, a large number of health-care workers are visiting households to trace active cases, and local health workers like ASHAs, Anganwadi workers, and ANMs are trained for surveillance activities under the guidelines of the Integrated Disease Surveillance Program (IDSP). Parameter control through thermal screening at all the entry and the exit points of red zones is protecting the further spread of the infection. About 15% of the patients are likely to require hospitalization, and an additional 5% will require critical care and ventilator management (MoHFW, 2020b). In view of this, temporary makeshift hospital facilities are made by converting hotels/guests, house/stadiums for mild cases, and dedicated COVID Health centers and COVID Hospitals are identified, which have isolation beds with oxygen support and other equipment. At present, 1,919 dedicated COVID hospitals having 1,73,746 isolation beds, and a total of 21,806 ICU beds are available, as reported by the Ministry of Health and Family Welfare on April 17.Our results indicate that current preventive measures have successfully helped in preventing a large number of deaths and confirmed cases in India. However, as the rate of screening increases in the coming days, there may be a sudden outbreak, which will subsequently increase the number of COVID-19 positive cases. Further, data also shows thatthe number of confirmed cases grew around 19 percent during 14-24 March 2020, that is, the pre-lockdown period and then stabilizes at the same pace till April 5. Post April 5, the decline in growth rate in confirmed cases continues attaining as low as 10 percent. Further, it is also important to highlight that during the pre-lockdown period, the doubling time for COVID-19 cases was in the range of 3-5 days, which has now increased to 7-8 days after the implementation of complete lockdown.

Way Forward

The whole world, including India, has been affected badly by the COVID-19 pandemic. Over the past few months, India has emerged as third worst affected country by the COVID-19 pandemic after USA and Brazil (Worldometers, 2020). As on July 5th, 2020, there were around seven lakhs cases reported in India, out of which 4.25 lakhs have recovered, and only 2.5 lakh cases are active. There have been around 20,000 fatalities due to COVID-19 in India till July 5th, 2020. The COVID-19 cases are more concentrated in the megacities like Mumbai, Delhi, Chennai, Ahmedabad, and Hyderabad, which are still increasing at a rapid pace after the unlock1.0. Several studies reported the positive impact of lockdown in reducing the infection all across the world (Lau *et al*., 2020; Sjodin *et al*., 2020). The control measures have helped in reducing the risk of COVID-19 infection in India, but still, India has to go a long way to combat the covid-19 crisis. With the ease in the lockdown from June 1, 2020, as the economic activities restarted, a surge in the number of cases has been seen, suggesting an alarming situation for public health facilities in India. Though the Government of India has issued SOP (Standard

Operating Procedures) for all the sectors, yet separate and more focused guidelines are needed in the megacities to contain the spread of infection in the future.COVID-19 pandemic has raised an alarm on public and private health care systems and its preparedness in India and urgently require pandemic planning, resources in terms of assessment, surveillance and prediction parameter which will help to effectively avert the future pandemics. With the improving recovery rate, flatten the COVID-19 curve in India still comes as a big challenge to the nation.

Limitations

At present, there are few published research articles about the prediction of COVID-19 spread in India using Susceptible-Infection-Recovered (SIR) and Susceptible-Exposed-Infection-Recovered model, Statistical Machine Learning (SML) models, Mathematical model, and deterministic endemic model, etc. In this paper, we have used the exponential growth model to predict the pandemic course in India, which may have overestimated the epidemiology of the disease. This model does not account for many predictive factors such as lockdown, healthcare-seeking behavior, quality of care, and community outbreak through mass gatherings. However, we have tried to account for the effect of lockdown, but many other vital factors such as co-morbidities and quality of care received by patients are not being included. Many studies have shown that COVID-19 has been fatal for the elderly and people with existing co-morbidities. Therefore, the number of deaths in the coming days may rise due to the presence of co-morbidities, the difference in the quality of care, and other associated demographic factors. Exponential model underestimated the public health care capacity of the country as it does not include the account of special facilities provided by the government with regards to combat COVID-19 (dedicated COVID-19 hospitals and test centers, temporary makeshift hospitals, arrangements of isolation beds for suspected cases, etc.). However, in this crucial period, with the limitations mentioned above, this study provides an elementary view of the pandemic curve, which may assist the preparedness action plan to combat this pandemic.

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