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Impact of Lockdown in India: A Case Study Comparing Karnataka with an International Model

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Abstract

The COVID-19 was declared a pandemic and a global health emergency by WHO, prompting various countries to implement early and stringent social distancing protocols through lockdown, to flatten the epidemic curve. The objective of the present study was to assess the impacts and effectiveness of the lockdown protocol in Karnataka and Punjab, compared with the implementation of this method in Australia and the UK. This study involved the collection of data from different authorized databases, in two phases. The first phase included the time starting with the first-reported index case through the 14th day after the declaration of lockdown, for each country. The second phase involved the data collected between the 15th day through the 28th day of the lockdown. The highest doubling rate for cases was observed in Australia, followed by Karnataka and Punjab, whereas the lowest was observed in the UK. Comparisons of the numbers of the samples tested, the mortality rate, and the recovery rate between Karnataka and Punjab, after the implementation of lockdown, revealed a better recovery rate and lower mortality rate in Karnataka than in Punjab. This study revealed that the implementation of social distancing and lockdown reduced the transmission of the coronavirus and the number of cases reported. However, the effectiveness of lockdown varied among locations, due to demographic and physiological differences.

Keywords: COVID-19, lockdown, outbreak, pandemic, social distancing

Introduction

Infections associated with the novel coronavirus severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), causing coronavirus disease 2019 (COVID-19), emerged in Wuhan, China, at the end of 2019, and rapidly spread to the United States, France, Italy, Spain, Iran, South Korea, India, Singapore, Japan, and other countries. Although the highest death rates were initially reported by China, this trend later shifted to European countries and the United States, forcing the World Health Organization (WHO) to declare the COVID-19 pandemic a global health emergency.[1] India implemented strict restrictions on the movement of citizens, in accordance with the epidemic disease act, on March 25, 2020, after a spike in COVID-19 cases was identified. Because India is the second-most populous nation in the world, the risk for a pandemic outbreak was thought to be especially high, due to undeveloped slum areas, unhygienic lifestyles, and the lack of health facilities.[2] Non-pharmaceutical forms of infection prevention, such as "social distancing", intended to prevent direct contacts with infected individuals, were proposed, resulting in the closure of all educational institutions, the restriction of non-essential travel, increased encouragement to work from home, and the complete cessation of all public transportation.[3] The initial plan for 21 days of national lockdown was followed by another phase of lockdown, lasting through May 3, 2020, which helped to flatten the curve and hold the mortality rate to 0.25% - 0.5% of total positive cases, compared to other developed countries.[4]

The negative impacts of the lockdown were reflected in the Indian economy, leading to the greatest economic emergency since the declaration of Indian independence. The International Monetary Fund has estimated that India's Gross Domestic Product (GDP) is likely to shrink, from 4.5% to 1.9%, due to the economic crises in the fields of marketing, industry, and networking.[5] Although India received a helpful contribution of approximately US $ 1 billion from the World Bank, to combat COVID-19, the impending financial crisis is inevitable.[6] However, the complete lockdown of India also had pos-

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itive effects, especially those associated with the environment, as an overall reduction in pollution has been observed in metropolitan cities. Additionally, during the spring and summer seasons, the rate of progression for the coronavirus is expected to be slower.[7]

The state Karnataka, in India, has achieved worldwide recognition for its efforts to prevent the spread of COVID-19, starting at the beginning of the pandemic, as part of the restrictions enacted by the government.[8] As Karnataka has continued its long and sustained battle to blunt the impacts of coronavirus, one-third of its districts have managed to keep the pandemic at bay. Although 18 deaths have been reported through April 25, 2020, the strict enforcement of lockdown appears to have helped, as 10 of 30 districts that have not reported a single COVID-19 case, thus far.[9] Another state in India, Punjab, followed strict curfew strategies and showed a reduction in mortality rate, up to 0.5%, and has controlled the number of new cases reported. When compared with other states in India, both of these states have been exceptional in addressing this pandemic, utilizing digital technologies for contact tracing and community surveillance. Thus, this study aimed to assess the impacts and effectiveness of the lockdown procedures implemented in Karnataka and Punjab, compared with the methods implemented in Australia and the United Kingdom (UK).

Method

A prospective, observational study was performed, to assess and compare the impacts of lockdown implementations between Karnataka, Punjab, Australia, and the United Kingdom (UK). The study involved the collection of data from authorized databases, performed in two phases. The first phase included the time from the first-reported index case through the 14th day after the declaration of lockdown, in each. The second phase involved the data collected between the 15th day and the 28th day of lockdown. This division was based on the incubation period for the virus, which can be as long as 14 days; therefore, cases reported during the first 14 days of lockdown may have been acquired prior to the commencement of lockdown. The authors collected data for cumulative cases, active cases, recovery rate, death rate, and the number of tests performed, for each of these time intervals. The ratio between positive case numbers and the number of tests performed was also assessed, to analyze the preparedness and testing strategies of the different regions.

The effects of lockdown were evaluated by comparing the doubling time for each region. The doubling time of an infectious disease or epidemic, in a population that is exhibiting exponential growth, refers to the time necessary for the infected population to double. Implicit in this definition is the fact that no matter when you start measuring, the population will always take the same amount of time to double.[10]

The exponential solution for a linear equation used to describe the relationship between cumulative case numbers and time is as follows:

$$PT = P_0 * b^T$$

where PT is the cumulative number of cases, reported as a function of time (T), P_0 is the initial case reported, and $b > 1$ indicates exponential growth.

We fit a linear, discrete, dynamical system model to the cumulative increase in reported cases, to determine the doubling time, as follows:

$$\text{Doubling time, } T_{double} = \log(2) / \log(b) \text{ [where } b > 1]$$

The doubling rates of the various regions were used to compare the effectiveness of the lockdown protocol in each region. The doubling rate from the first-reported index case through the 14th day of lockdown and the doubling rate between the 15th and 28th days of lockdown were analyzed. Higher doubling rates indicate a reduced rate of spread and a more effective lockdown protocol. Increases in the doubling rates were analyzed for Karnataka, Punjab, Australia, and the UK. Moreover, the percentage reduction in the cases was assessed, relative to the number of cases that were predicted without the implementation of lockdown, to determine the effectiveness of the lockdown protocol for each region.

The daily reported data for the number of new cases, the number of recovered patients, the mortality rate, the number of samples tested, and total cases reported obtained before and after lockdown, through the 28th day, from WHO sites and official medical bulletins.

Statistical analysis was performed using software for statistical analysis. Demographic variables, including the age and gender of COVID-19 patients in Karnataka, were assessed and presented as percentages. The ages of patients who tested positive for COVID-19 during both phases of lockdown were also assessed. The percentages of active and recovered cases were analyzed. The growth rates in the numbers of reported cases were measured during pre- and post-lockdown phases.

The testing strategies for Karnataka and Punjab were analyzed. The total populations of both states and the total number of samples tested, before April 1, 2020, and between April 1 and April 25, 2020, were assessed. The ratio between the total number of tests performed and the total population was determined for both periods. The number of tests required to detect a positive case was also assessed, as the ratio between total cumulative COVID-19 cases and the number of tests performed.

The comparisons of the death rate and recovery rate

were expressed in percentages and represented as bar diagrams.

The doubling rates and the predictions of the total numbers of cases were calculated by assuming that case growth represented an exponential model. The equation of the line was used to assess the doubling rates and predictions, and R^2 values were assessed to evaluate the model fitness.

The doubling rate and case projections were analyzed in two phases, to analyze the efficiency of the lockdown in each assessed region.

Improvements in the doubling rates between pre- and post-lockdown conditions were assessed, and the impacts of the lockdown were assessed as the percentage reduction in the occurrence of actual cases relative to the number of predicted cases.

Results

In Karnataka, between January 25, 2020, and April 25, 2020, 500 cases of COVID-19 were identified, including the index case, among which 158 (32%) recovered, 324 (64%) remained active cases, and 18 (4%) died. Of these 500 cases, 356 were men and 144 were women (Table 1).

The average daily growth rate in positive COVID-19 cases, which was 13.52% from March 8 until the implementation of lockdown, was reduced to 4.15% after the implementation of lockdown. The cumulative growth rate for positive COVID-19 cases in Karnataka declined, compared with the cumulative growth rate in COVID-19 cases for all of India (Figure 1).

Examining the number of samples tested for suspected COVID-19-positive cases showed that Punjab had tested a larger proportion of its population than Karnataka. Based on the population, more tests were necessary to identify a case in the suspected population after a lockdown in Punjab (Table 2).

Comparisons of the recovery rates, death rates, and total cases between Karnataka and Punjab showed an increased recovery rate and a reduced mortality rate for Karnataka compared with Punjab after April 1, 2020, whereas Punjab showed a higher recovery rate and reduced mortality rate than Karnataka before April 1, 2020

Table 1. COVID-19-Positive Cases in Karnataka, India, Distributed by Age

Age (years)	COVID-19-Positive	
	Before April 1, 2020	April 1–April 25, 2020
0–5	0	7
5–10	4	14
10–20	16	42
20–30	21	122
30–40	27	125
40–50	14	67
50–60	8	52
> 60	20	71

Table 2. Numbers of COVID-19 Tests for the Total Population

State	Karnataka	Punjab
Total population	6,6834,193	3,073,507
No. of samples tested before April 1, 2020	3,254	1,260
Total test / population before April 1, 2020	20,539.09	24,392.91
No. of samples tested till April 25, 2020	35,378	13,270
Total test / population through April 25, 2020	2,325.153	2,316.132
Tests required to identify a positive case in the suspected population before April 1, 2020	285.2651	27.08696
Tests required to identify a positive case in the suspected population through April 25, 2020	5.432	7.4955

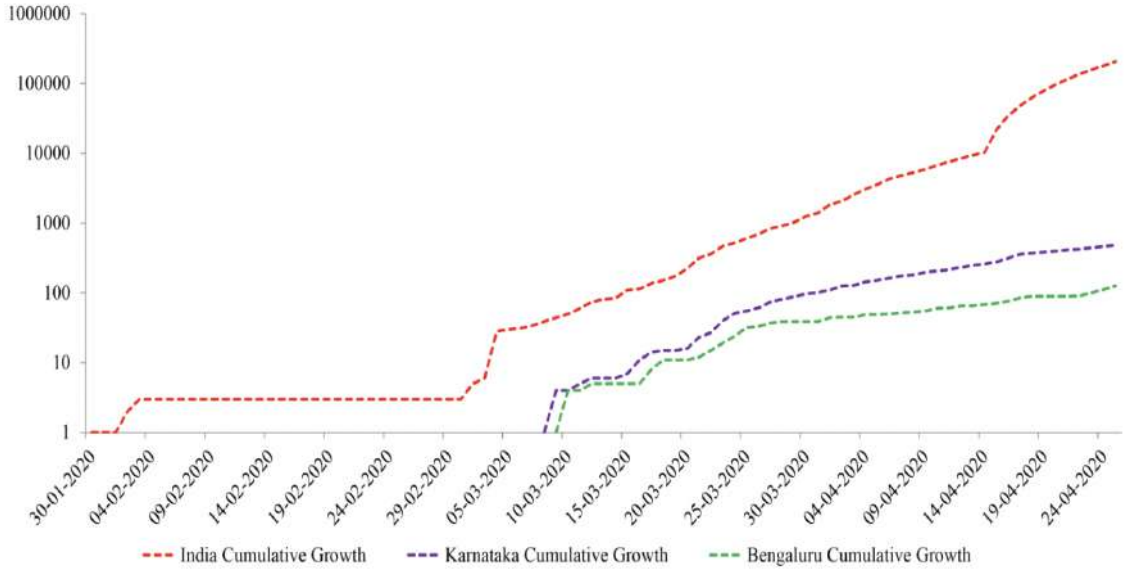

Figure 1 – Total Positive COVID-19 Total Cases in India, Karnataka, and Bengaluru

(Figure 2).

To determine the impact of lockdown, we divided the examined period into two phases. The first phase included the time from the first-reported index case through 14 days after the declaration of lockdown. We assumed that cases reported during the first 14 days of lockdown may have been acquired before the lockdown declaration, due to the incubation period of COVID-19. During the second phase, we included the period starting 14 days after the declaration of lockdown.

Karnataka reported its first COVID-19 case on March 9, 2020. Then, a complete lockdown was initiated on March 25, 2020. During the lockdown period, approximately 428 cases were reported. The doubling time before lockdown for Karnataka was calculated to be 6.35 days ($R^2 = 0.89$). The overall doubling time during the lockdown phase was found to be 2.46 days (R2 = 0.96), and the doubling rate for cumulative cases decreased after the initiation of lockdown.

In Punjab, 332 cases were reported, with 17 deaths. Their first index case was reported on March 5, 2020, and they declared complete lockdown on March 25, 2020. During the lockdown period, Punjab reported approximately 309 cases. The doubling time for Punjab, before the lockdown was determined to be 4.85 days ($R^2 = 0.87$). The doubling time for Punjab after the lockdown was found to be 3.35 days ($R^2 = 0.87$).

In Australia, 6,675 total COVID-19 cases and 78 deaths were reported through April 25, 2020. They announced a lockdown on March 23, 2020, which was 58 days after the diagnosis of the index case, on Jan 25, 2020. By the time lockdown was implemented, approximately 5,285 cases were reported. The doubling time lockdown in Australia was found to be 8.13 days ($R^2 = 0.95$). During the second phase, we examined the period after the 14th day of the declaration of lockdown, and the overall doubling time for this period in Australia was 7.2 days ($R^2 = 0.97$)

In the UK, 119,908 positive cases and 15,464 deaths were reported through April 25, 2020. They announced a lockdown on March 23, 2020, which was 53 days after the first-reported index case, on January 31, 2020. During this lockdown period, the UK reported approximately 114,221 COVID-19-positive cases. The doubling time before the lockdown in the UK was found to be 4.32 days ($R^2 = 0.97$). The doubling time after the lockdown in the UK was found to be 4.06 days ($R^2 = 0.959$). Although the UK improved the overall doubling rate because of lockdown, an extension of lockdown is necessary to increase the doubling time.

The efficiency or the impact of lockdown for reducing the infection spread can be determined by assessing the rise in the doubling rate from the first phase to the second phase. The largest observed increase in the doubling rate occurred in Karnataka (2.41 days), followed by Punjab (1.49 days). The doubling rate in Australia increased by 0.92 days, whereas the lowest increase was observed for the UK, which was 0.26 days illustrating the necessity of prolonging the lockdown rate and implementing stricter measures for disease control in the UK.

The percentage in case reduction attributed to lockdown was determined relative to the predicted cases and was found to be highest for Punjab (95%) and the lowest for the UK (74%) (Table 3).

Discussion

The COVID-19 epidemic caused a unique and alarming situation, requiring the implementation of new strategies to control the transmission of infection. In this study, we assessed the impacts of lockdown in four regions, include Karnataka, Punjab, Australia, and the UK, to provide a comprehensive analysis of the COVID-19 outbreak. We analyzed the estimated epidemic size when social distancing was activated in different regions, on dif-

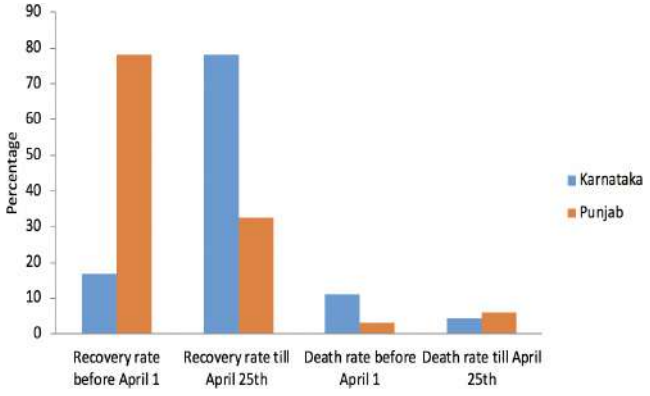

Figure 2. Comparisons of the Death Rates, Recovery Rates, and Total Cases between Punjab and Karnataka

Table 3. COVID-19-Positive Projections, with and without Lockdown

Place	Total Cases		Percentage Reduction from Predicted Cases
	Reported with Lockdown	Predicted without Lockdown	
UK	114,221	436,665.6	73.85%
Australia	5,285	23,830	77.83%
Karnataka	428	4,953.561	91.35%
Punjab	309	6,697.687	95.33%

ferent dates, by determining the doubling time. An increase in the doubling time implies a slowdown in transmission.[11] The highest doubling rate was identified for Australia, followed by Karnataka and Punjab, whereas the lowest was identified for the UK. However, as a result of the lockdown, the rise in the doubling rate was the highest for Karnataka and the lowest for the UK. Compared with the number of predicted cases if lockdown had not been implemented, the number of cases reported after the implementation of lockdown was significantly lower than the number that was predicted without lockdown. Thus, the lockdown implementation likely lowered the epidemic spread in all 4 regions. Rodriguez, *et al.*,[12] observed an increasing trend in the doubling time for the coronavirus among the Chinese population during February 2020.

When comparing the numbers of samples tested, the mortality rates, and the recovery rates between Karnataka and Punjab, after the implementation of lockdown, an increased recovery rate and a reduced mortality rate were observed for Karnataka compared with those in Punjab, and Karnataka also displayed a high rate of sample testing compared with that in Punjab. A similar study suggested that to control the epidemic size and death rate, earlier social distancing rules should be followed, without lockdown.[13] As Karnataka continues its long and sustained battle to blunt the impacts of COVID-19, through the use of a functional disease surveillance system, one-third of its districts have managed to keep the pandemic at bay.

When the demographic features of Karnataka were compared with those of other countries, age and gender were found to be significant factors for determining the impacts of lockdown. Similar to the observations reported globally, the majority of COVID-19 patients identified in the state of Karnataka are between 30 and 40 years of age. Almost 500 total cases were reported, of which 32% of them recovered and more than 64% of cases remained active. The death rate was maintained under 4%, as part of Karnataka's contingency action plan for the control of the epidemic. The plan included a strategy consisting of community surveillance, quarantine, fever clinics, COVID-19-specific hospitals, multiple testing centers, personal protective equipment, and a rapid response team for COVID-19 disaster management.[14] After the outbreak of the coronavirus, the government of Karnataka executed a strict protocol, including the closure of educational establishments, the prevention of non-essential travel, the maintenance of hygiene and physical distancing, and screening, at all airports, railway stations, and state borders. In Punjab, the first case was reported on March 5, 2020, and through April 25, 2020, approximately 309 confirmed COVID-19 cases were reported, with a 5% mortality rate. They also implemented a lockdown strategy, maintaining a fine balance between allowing normal economic activities and controlling COVID-19. Punjab's COVID-19 action plan, which consisted of a task force to contain the spread of the coronavirus, required changes in human behavior, including maintaining physical distances, limiting mobility, and performing rigorous personal hygiene.[15]

Australia's COVID-19 plans were also highly successful in flattening the curve of the new COVID-19 cases through April 25, 2020, with 6,675 total cases and 78 deaths reported. The emergency response plan of the Australian health sector was successfully implemented by the government, to allow the population to continue living and working in a COVID-19-safe manner. They are now capable of keeping the number of cases low while taking steps to relax restrictions.[16] As a part of the drastic lockdown, they closed their borders to non-residents, enacted stringent social distancing protocols, and were able to mitigate the rapid spread of the coronavirus.[17]

The UK government was well-prepared for disease outbreak, as they learned during the outbreak of an influenza pandemic, over a decade ago.[18] The overall phases of the UK COVID-19 action plan included the containment, delay, and mitigation of any outbreak, using research to inform policy development. Based on the available scientific evidence, they were focused primarily on the continuity of public, the stability of the economy, and the provision of critical services in the fight against COVID-19.[19] The other preventive measures included social distancing, information campaigns regarding personal hygiene, and rapid testing. Thus, the UK continues to respond robustly to various pandemic outbreaks, to maximize the effectiveness of their public health and care system.[20]

Our study is subject to some inherent limitations, including the under-reporting of cases due to under-diagnosis, the unavailability of data regarding mortality, tested cases and confirmed cases from different countries.

Conclusion

Our study reveals that the implementation of social distancing and lockdown impacted the transmission of coronavirus and the number of cases reported. However, the effectiveness of lockdown varied among regions, depending on multiple factors, including demographic variables, population density, and social gathering. Therefore, lockdown appears to represent an effective method for flattening the exponential curve associated with the COVID-19 pandemic.

Abbreviations

SARS-CoV-2: Severe Acute Respiratory Syndrome Coronavirus 2; COVID-19: Coronavirus disease 2019; WHO: World Health

Organization; GDP: Gross Domestic Product; UK: United Kingdom.

Ethics Approval and Consent to Participate
Not Applicable

Competing Interest
There are no conflicts of interest.

Availability of Data and Materials
The datas used and/or analysed during the current study are available from the author on reasonable request.

Authors' Contribution
Stelvin Sebastian and Aby Paul conceived the study and drafted the research protocol. Stelvin Sebastian, Aby Paul, Jeeva Joseph and Joel Joby provided critical review of and approved the study design. Sanjo Saijan conducted the database searches. Aby Paul made the primary selection of eligible papers including data extraction. Jeeva Joseph, Aby Paul and Jobin Kunjumon Vilapurathu supervised and checked the study selection process and data extraction. Sanjo Saijan analysed the data. All authors contributed to interpretation of the analysis. Stelvin Sebastian and Aby Paul wrote the manuscript. All authors provided critical review and approved the final manuscript.

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Additional Information
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