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## The impact of lockdown strategies on the basic reproductive number of coronavirus (COVID-19) cases in Saudi Arabia

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## ABSTRACT

**Background & Objectives:** In late December 2019, an outbreak of severe acute respiratory syndrome coronavirus 2 (SARS COV-2) occurred in the city of Wuhan, the capital of the Hubei province in the central part of the People's Republic of China (Ren et al., 2020). In Saudi Arabia, the first case of COVID-19 was reported in March 2, 2020. In March 8, 2020, the Saudi authorities adopted the lockdown strategy to contain the disease. The aim of this study was to determine the effectiveness of the various phases of the lockdown strategy in Saudi Arabia and its impact on the basic reproductive number (R0) of the COVID-19 outbreak.

**Material and Methods:** The timeline of the COVID-19 outbreak in Saudi Arabia was divided into three-time intervals. *Google Mobility Community Reports* (2020) was used to estimate the changes in community mobility during the various phases of the lockdown. The basic reproductive number (R0) of the COVID-19 outbreak was calculated daily using the Susceptible, Infected and Recovered (SIR) model based on the Saudi Ministry of Health (MOH) daily reports. This is a standard system to determine the spread of the virus on the basis of infection rate, quarantine rate as well as confirmation rate. The mean values of the calculated R0 during each interval were compared using one-way ANOVA test.

**Results:** There was no statistically significant difference between the mean values of the different phases of the lockdown ( $P > 0.05$ ). Moreover, mean R0 value of the second interval was 0.09 higher than the initial interval with free community mobility. Furthermore, the mean R0 values of the third interval with the full lockdown was 0.28 higher than the initial interval.

**Conclusion:** Early implementation of lockdown strategy combined with other social distancing strategies help in containing infectious outbreaks in their early phases. Continuous assessment of such strategies' effectiveness provides decision makers with precious information needed to justify their application when considering their economic impact.

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### 1. Introduction

Controlling a pandemic is a complicated task because it involves multiple stakeholders, starting with citizens and ending with health care providers and other governmental authorities. In late December 2019, an outbreak of severe acute respiratory syndrome coronavirus 2 (SARS COV-2) occurred in the city of Wuhan, the capital of the Hubei province in the central part of the People’s Republic of China (Ren et al., 2020). On January 9, 2020, the Chinese authorities notified the World Health Organization (WHO) of this outbreak. Accordingly, the WHO issued a statement about those cases and concluded that given the then available information, no specific precautions needed to be considered for travelers to China and no restrictions were needed against trade with China (Agosto et al., 2020). However, three weeks later the government of China reacted rapidly to the increasing number of cases: It declared the city of Wuhan as a source of new outbreak and implemented a lockdown of the Hubei province in an attempt to control the disease and limit its spread to other Chinese provinces and neighboring countries (Lau et al., 2020).

Despite the early implementation of a lockdown strategy in the Hubei province, more cases were identified in other parts of China because some travelers from the epidemic area (Wuhan) had carried the disease asymptotically to other cities before the lockdown (Bai et al., 2020). Those dispersed cases were isolated in quarantine together with additional suspected cases to limit the spread of the disease. On January 8, 2020, the first case outside of China was reported in Thailand. As of January 31, 2020, other countries, including the Republic of Korea, Japan, Cambodia, Vietnam, Malaysia, Sri Lanka, Taiwan, the Philippines, India, United Arab Emirates, Australia, Canada, the United States, Germany, Finland, and Italy, had reported positive COVID-19 cases to the WHO, which consequently declared the outbreak an international emergency.

In epidemiology, the epidemiological triad concept works as the basic guideline for understanding the process of diseases and allows public health officers to control these diseases more efficiently. In the case of the COVID-19 pandemic, the epidemiological triad is formed by SARS COV-2 as the agent, the human as the host and fomites, and respiratory droplets and aerosols as the environ-

ment (Galbadage et al., 2020). The epidemiologic problem-oriented approach is a method of approaching epidemiologic problems systematically by building on the aforementioned epidemiological triad to facilitate the management of the problem through systematically customizing the approaches to the triad corners and building the solutions triad (Fig. 1) (Abdalla et al., 2011). Among these approaches is the social distancing strategy, which was applied by the Chinese authorities as part of their community mitigation efforts and helped to control the basic reproduction number of cases in China. Accordingly, these community mitigation measures, which included a lockdown strategy, gained a positive reputation in European countries such as Italy, where the authorities implemented a partial lockdown strategy (starting from 6:00 p. m.) in the entire nation. In Saudi Arabia, the first case of COVID-19 was reported on March 2, 2020. On March 8, 2020, the Saudi authorities adopted the same European partial lockdown strategy by applying a selective lockdown of the Qatif region, where the first cases were identified. However, by March 24, 2020, this lockdown was extended to include all provinces of Saudi Arabia, starting from 7:00 p.m. until 6:00 a.m. Moreover, traveling between the different provinces of Saudi Arabia was prohibited. On April 2, 2020, the Saudi authorities furthered the lockdown strategy by subjecting the holy cities of Makkah and Madinah to a 24-hour lockdown. The cities of Riyadh, Dammam, Khobar, Hofuf, Dharan, Qatif, Jeddah, Taif, and Tabuk were included four days later (Saudi Press Agency, 2020a).

The aim of this study was to determine the effectiveness of the various phases of the lockdown strategy in Saudi Arabia and its impact on the basic reproductive number (R0) of the COVID-19 outbreak, which is an estimate of the average number of secondary cases produced by a typical infection case in a susceptible population. The results will provide decision makers with an estimation of the actual impact of the various lockdown strategies.

### 2. Material and Methods

The timeline of the COVID-19 outbreak in Saudi Arabia was divided into three time intervals. The first interval started on March 2, 2020, when the first case of COVID-19 disease was

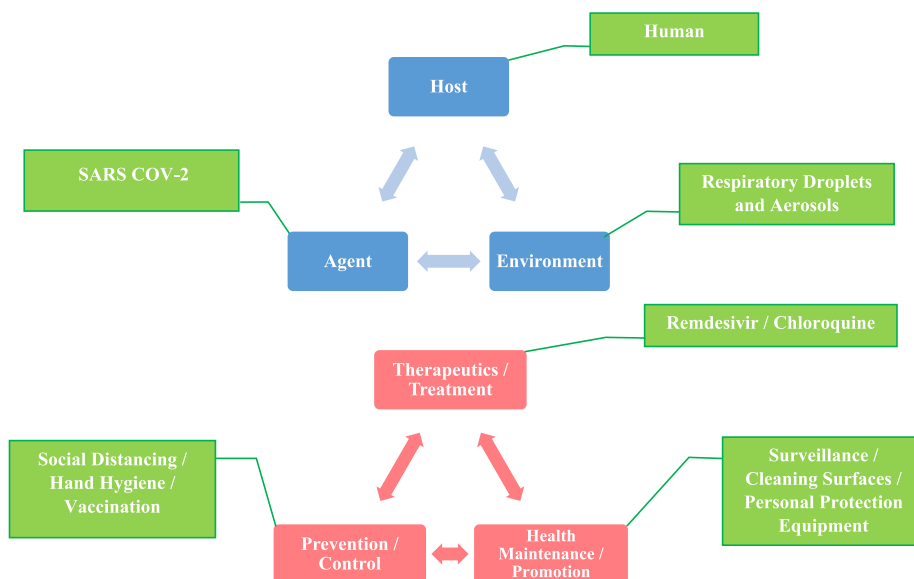


Fig. 1. The Epidemiologic Problem-Oriented Approach with Solutions Triad for COVID-19 Disease.

reported in Saudi Arabia, and ended on March 23, 2020, the last day before the first partial lockdown strategy was applied in all provinces of the country. The second interval started from March 24, 2020, the day the first partial lockdown strategy was applied, and ended on April 5, 2020, the last day before the application of the full lockdown strategy. The third interval started on April 6, 2020, the day when the full lockdown strategy was applied, and ended on April 19, 2020. *Google Mobility Community Reports* (2020), which utilize mobile phone users' data to provide an estimation of the community movement within the country, were used to estimate the changes in community mobility during the various phases of the lockdown (Google COVID-19 community mobility report). The reports chart movement trends over time by geography, across different categories of places such as retail and recreation, groceries and pharmacies, parks, transit stations, workplaces, and residential (<https://www.google.com/covid19/mobility/>) (Google, 2020). The R0 was calculated daily using data from the Saudi Ministry of Health (MOH) (Ministry of health, 2020) daily reports on the COVID-19 outbreak in Saudi Arabia. MOH reports follow the Saudi Center for Disease Prevention and Control (Saudi Center for disease prevention and control, 2020) guidelines in diagnosing and reporting COVID-19 cases (Saudi Center for Disease Prevention and Control). The case was included in the study if it met CDC criteria for COVID-19 diagnosis and was reported by the MOH in its daily report. This include a Patient with sudden onset of at least one of the following: headache, sore throat, rhinorrhea, nausea or diarrhea with laboratory confirmation of COVID-19 infection. The following equation (Gu et al., 2020) was used to estimate initial R0 value:

$$R0 = \frac{f * (1 - \alpha) * E(T)}{h}$$

Where R0: is the basic reproductive number, f: is the infection rate calculated as the number of cases to the total susceptible population of Saudi Arabia, which is 34,218,169 people, based on both MOH daily reports and the Saudi Authority for Statistics (Saudi authority for Statistics, 2019),  $\alpha$ : is quarantine rate (cases that were isolated in quarantine to the total number of confirmed cases), E(T): is the mean incubation period and was estimated by taking the mean of the average incubation period from other reports around the world  $E(T) \approx 7.5$ , and h: is the confirmation rate of the cases based on MOH reports.<sup>14</sup> Accordingly, f &  $\alpha$  were calculated daily using the following equations:

$$f = \frac{\text{Total Confirmed Cases}}{\text{Total Susceptible Population of Saudi Arabia}}$$

$$\alpha = \frac{\text{Old Confirmed Cases}}{\text{Total Confirmed Cases}} \\ \times (\text{Since all confirmed cases were quarantined by MOH})$$

h was calculated using the data from the MOH daily report of April 19 using the following equation (Ministry of Health. *COVID-19 Monitoring Committee highlights outcomes of active surveillance*):

$$h = \frac{\text{Total Confirmed Cases as of April 19th, 2020}}{\text{Total Tests as of April 19th, 2020}}$$

The mean values of the calculated R0 during each interval were compared using a one-way ANOVA test to assess if there was any statistically significant difference between the mean values of R0 during the various phases of the lockdown followed by Tukey Post-Hock test.

### 3. Results

The total number of confirmed COVID-19 cases in Saudi Arabia by the end of the last day of the third interval was 9,374. The first confirmed COVID-19 case in Saudi Arabia was recorded on March 2, 2020. The mean of R0 values during the first interval, without lockdown (100% community mobility), was 1.18. During the second interval, when the partial lockdown strategy was applied (46% community mobility), the mean of the R0 values was 1.27. The mean of R0 values during the third interval, which is the interval with the full lockdown (28% community mobility), was 1.46 (Table 1 and Fig. 2). There was no statistically significant difference between the mean values of the different phases of the lockdown ( $P > 0.05$ ). Moreover, the mean R0 value of the second interval was 0.09 higher than the initial interval without lockdown. Furthermore, the mean R0 values of the third interval with the full lockdown was 0.28 higher than the initial interval (Table 2).

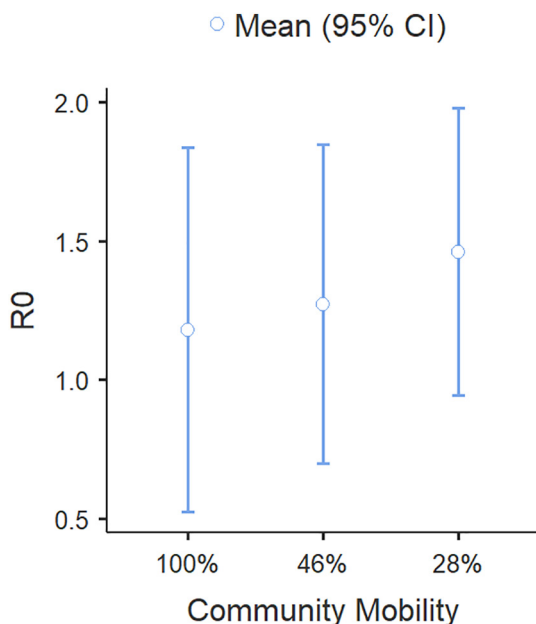
### 4. Discussion

Studies to evaluate the impact of lockdown strategies on the COVID-19 pandemic's progression are limited. However, Lau et al. reported a positive impact of the lockdown strategy on COVID-19's progress in Wuhan, China. In other words, the lockdown strategy applied by the Chinese government helped increase the doubling time for cases significantly from two days to four days. The authors of another study in China reported a reduction in incidence and mortality rates following the application of the lockdown strategy, which helped contain the outbreak in Hubei and Guangdong provinces. Moreover, the group concluded that an effective reduction in the incidence after the application of the lockdown strategy would be expected between the fifth and the eleventh days from the effective beginning of lockdown (Figueiredo et al., 2020). However, the effectiveness of these lockdown and social distancing strategies in containing epidemics is still under academic debate (Kelso et al., 2019). Zhang et al. reported a significant reduction in the R0 of COVID-19 cases in Wuhan (Zhang et al., 2020). The R0 was 2.2 during the first week of the outbreak, dropping to 1.58 following the effective application of the lockdown strategy for 30 days. The authors concluded that early implementation of lockdown strategies at the epicenter of the epidemic, followed by supportive lockdown of adjacent provinces, helped in containing the outbreak (Zhang et al., 2020). In Saudi Arabia, the early implementation of the lockdown strategies helped maintain low R0 values. Our study results indicate that R0 values were kept below the level of 1.50 during the first two months of the outbreak in Saudi Arabia. In other words, early implementation of lockdown combined with social distancing was an effective strategy in containing the infectious outbreak of COVID-19 in Saudi Arabia. Our outcomes are similar to a study done earlier in Saudi Arabia. The study emphasized the result of effective lockdown strategies with a significantly lowered number of confirmed cases. With the help of validated mathematical model, it estimated several fold increase in the number of positive cases without lockdown in the Kingdom of Saudi Arabia (Alrashed et al. 2020).

Despite its positive results in containing the pandemic, many governments and states were hesitant in applying the lockdown strategy because it has a huge economic impact and needs to be justified prior to its application. The lockdown strategy from an economic point of view was evaluated and judged such a strategy to be a plan for failure (Hirschhorn and Emeritus, 2020). They described the situation as if the government was distributing money to help people but there was nothing to buy, which in turn would result in an economic inflation.

**Table 1**  
Showing the descriptive statistics and the p-value.

One-Way ANOVA (Welch's)					
	F	df1	df2	P	
R0	0.280	2	29.8	0.758	
Group Descriptives					
	Community Mobility	N	Mean	SD	SE
R0	100%	22	1.18	1.482	0.316
	46%	13	1.27	0.949	0.263
	28%	14	1.46	0.896	0.240



**Fig. 2.** Showing the descriptive plots of the different R0 means.

**Table 2**  
Showing Tukey Post-Hoc Test summary.

Tukey Post-Hoc Test – R0				
		100%	46%	28%
100%	Mean difference	–	–0.0929	–0.281
	p-value	–	0.974	0.776
46%	Mean difference	–	–	–0.188
	p-value	–	–	0.914
28%	Mean difference	–	–	–
	p-value	–	–	–

Note. \* p < .05, \*\* p < .01, \*\*\* p < .001.

Moreover, extended lockdown would negatively affect small businesses, which employ 34% of the total workforce in the United States (Hirschhorn and Emeritus, 2020). To that end, complete lockdown applied during the initial phases of an outbreak would be effective if it lasted for two weeks. Late application of such strategy, two months after the initial outbreak, would require extending it for at least 30 days to aid in containing the infection. If the authorities decided to go ahead with a partial lockdown, it should last for one month to show its effectiveness if it was applied during the initial phases of the outbreak. Late application of a partial lockdown would require two months to positively control the disease progression (Piguiilem and Shi, 2020).

In Saudi Arabia, the decision makers were wise enough to implement such a strategy despite its huge economic impact. The application of the lockdown in Saudi Arabia started three weeks after the first confirmed case in the country. The lockdown was applied gradually to the main cities of Saudi Arabia because the government applied, in the first phase, a partial lockdown to help minimize the expected economic damages. Two weeks later, the decision makers adopted the full lockdown strategy in an attempt to maintain the number of new cases to a level that the Saudi health care system could tolerate. However, despite the early implementation of the lockdown strategy in Saudi Arabia, the mean R0 value during the application of the full lockdown strategy in the country was higher as compared to the initial phases of the outbreak. This is attributed to the active surveillance conducted by the MOH during the last interval of our study, resulting in early detection of positive COVID-19 cases and increasing the R0 value. Moreover, in the last two intervals of our study, King Salman Bin Abdulaziz ordered via a royal decree that all residents of the country were eligible for free medical care during the outbreak regardless of their residency status, which improved the accessibility to health care, resulting in an increase in the number of cases (Saudi Press Agency, 2020b). In conclusion, early implementation of lockdown strategy combined with other social distancing strategies help in containing infectious outbreaks in their early phases. Later implementation calls for prolonged application that will affect the economy negatively. Continuous assessment of such strategies' effectiveness provides decision makers with precious information needed to justify their application when considering their economic impact.

### 5. Study limitations

The use of the R0 to evaluate the effectiveness of lockdown strategies by determining how fast the disease spreads from one individual to another does not take into consideration the individual variation in terms of exposure to others. In other words, health care providers can be considered as “super spreaders” during an outbreak because they are more prone to the infection and might spread the disease to their patients and colleagues as a result of not being able to comply with lockdown strategies. This scenario might increase the R0 and create a false conclusion that the lockdown strategy is not working (Wu and McGoogan, 2020). Moreover, on March 30, 2020, King Salman Bin Abdulaziz ordered, via a royal decree, that all residents of Saudi Arabia were qualified to receive free medical care in case of infection of the COVID-19 disease, even if they were illegal residents of the country. This order improved all residents' accessibility to health care services, which increased the number of COVID-19 patients reported to the Ministry of Health; accordingly, the R0 might increase again and create a false impression that the lockdown strategy is not effective. Another limitation is that the time intervals are short and do not allow an accurate assessment of the effectiveness of the lockdown strategy in lowering the R0. For example, the second interval, when the partial lockdown strategy was active, lasted for only 13 days, whereas the incubation period of SARS COV-2 that causes the COVID-19 disease ranges from 5 to 14 days (Lauer et al., 2020). Also, google mobility report covers only those individuals who possess electronic gadgets, mobile phone or other devices that has GPS tracking system, therefore google mobility report is not cent percent representation of mobility but just gives a trend to analyze.

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## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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