Effect of epidemic management and control plan on COVID-19 mortality in Iran: an interrupted time series analysis

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Key words
COVID-19 • Control Measures • Iran • Mortality

Summary
Background. Globally, several measures have been taken to decrease COVID-19 mortality. However, the effectiveness of preventive measures on the mortality related to COVID-19 has not been fully assessed. Thus, the present study aimed to assess the success of COVID-19 epidemic management and control plan on the mortality associated with COVID-19 in Iran from February 19, 2020, to February 5, 2021.

Methods. In the current quasi experimental study an interrupted time series analysis of daily collected data on confirmed deaths of COVID-19 occurred in Iran and in the world, were performed using Newey ordinary least squares regression-based methods.

Results. In Iran, the trend of new deaths increased significantly every day until 24 November 2020 according to pre-intervention slope of \((\text{OR} 1.14, 95\% \text{ CI} 0.96 - 1.32,\); \(P < 0.001\)). The occurrence of new deaths had a decreasing trend after November 24, 2020, with a coefficient of \((\text{OR} -5.12, 95\% \text{ CI} -6.04 - -4.20,\); \(P < 0.001\)). But in the global level daily new deaths was increasing before \((\text{OR} 18.66, 95\% \text{ CI} 14.41-2292; \ P < 0.001)\) and after the 24 November 2020 \((\text{OR} 57.14, 95\% \text{ CI} 20.80 - 93.49; \ P: 0.002)\).

Conclusions. Iranian COVID-19 epidemic management and control plan effectively reduced the mortality associated to COVID-19. Therefore, it is essential to continue these measures to prevent the increase in the number of deaths.

Introduction

The number of deaths from COVID-19 continues to increase universally, and the first COVID-19 death was formally reported in Iran on February 19 2020 [1]. On March 1, the Ministry of Health and Medical Education (MOHME) stated 135 new deaths [2]. On March 20 (Nowruz; The first day of the Iranian New Year), 149 deaths were reported. On April 4 (The day after the Iranian New Year holidays), daily new deaths had increased to 158 [2]. On June 14, daily deaths touched over 100, with 107 deaths reported [2]. This reduction is stated to be due to a social distancing started formally by the Iranian government in late March 2020 of to March 2020 [3]. On June 29, MOHME reported a new record figure of deaths in a day, with 162 deaths [2]. On July 7, the number of fatalities jumped by 200 deaths [2]. On October 19, 2020, Iran topped the list with 337 new deaths [2]. October 28 On November 16, another rise of 486 deaths was reported [2]. According to some mathematical models, the number of daily deaths in the country in December was predicted to reach more than 800 per day [4]. To deal with this terrible increase in the number of deaths from the disease, on November 10 Nov, the COVID-19 epidemic management and control plan was implemented by the MOHME in a family-oriented manner [5]. The plan’s goal was to break the transmission chain and reduce deaths from COVID-19 disease with the help of non-governmental organizations (NGOs) and through supportive coverage of high-risk groups in the community [5]. As of November 21, over 1.4 million out of 3 million families in Tehran have undergone screening [5]. The plan is designed in three phases of care, support, and monitoring [5]. In the support phase, to cut the transmission chain and reduce the contact of infected people, through which, 40 centers in Tehran receive COVID-19 patients who cannot quarantine at home [5]. Also, from the beginning of December 2020, the government completed the plan by intensifying social distancing measures [5]. In this plan, the status of cities across the country is divided into three categories: yellow, orange, and red, based on the number of patients admitted whose disease was confirmed by PCR [5]. Restrictions were then placed on long-distance travel, closure of offices and unnecessary jobs depending on the situation in each city [5]. At February 5, 2021 Iran in terms of the number of deaths due to COVID-19, is ranked 11th after the United States, Brazil, Mexico, India, the United Kingdom, Italy, France, Russia, Germany and Spain [2]. The effectiveness of the control measures implemented in Iran on COVID-19 mortality has not been fully investigated. This is essential to improve ongoing health decisions and responses to similar pandemics in the future. The present study aimed to explore the efficacy of preventive measures undertaken by the Iranian government aimed to investigate the
effectiveness of preventative measures undertaken by the Iranian government to reduce the mortality related to COVID-19 among the Iranian population from February 19, 2020 to February 5, 2021.

Methods

We did an interrupted time series analysis (ITS) of daily collected data on confirmed deaths of COVID-19 occurred in Iran and in the world, from February 19, 2020, to February 5, 2021. The dataset which is available at (https://ourworldindata.org/coronavirus) was used in the current study. The data included 351 observations of the death occurred in Iran and the world. Although COVID-19 epidemic management and control plan started formally in November 10, 2020, Due to the Incubation period of this infection, November 24, 2020, considered as the starting time of preventive measures in the analysis. Findings from the Princess Diamond cruise ship shows that deaths occurred about 14 days after the time which the Index case was identified [6]. Hence, it is rational that one assesses the COVID-19 mortality with a two-week delay in this case. So, in the current analysis deaths occurred before November 24, 2020, were considered as control period, while deaths occurred after November 24, 2020, were considered as the intervention period in Iran. However, the starting date of the COVID-19 epidemic management and control plan was November 1010, 2020, in the current analysis, November 24, 2020 was considered as time of intervention start. This is also is in accordance with the average incubation period of the SARS-CoV-2 which has been reported to be 5.1 days [7]. Segmented regression model and ITS analysis using Newey ordinary least squares regression-based methods were used. The standard ITS regression model was as follows [8, 9]:

\[
y_t = \beta_0 + \beta_1 T_t + X_t + \beta_3 X_t T_t + e_t
\]

\(Y_t\) is the aggregated number of deaths that occurred at each time point \(t\), \(T_t\) is the time since the first day of the study, \(X_t\) is representing the intervention (pre-intervention periods 0, otherwise 1), and \(X_t T_t\) is an interaction term. The \(\beta_0\) represents the intercept. \(\beta_1\) is the slope of the trend of deaths before the start of the intervention. \(\beta_2\) represents the change in number of deaths in the period after the start of the intervention. \(\beta_3\) represents the difference between pre-intervention and post-intervention slopes of the trend of deaths. A significant \(\beta_2\) shows an effect immediately after the intervention, while a significant \(\beta_3\) means an effect over the time [10, 11]. In order to attribute the observed change in the number of deaths before and after the implementation of the Iranian COVID-19 epidemic management and control plan, the correlation between the number of daily deaths due to COVID-19 in Iran and the world was examined in two-time stages before and after November 24, 2020. All analyzes were done using Stata Corp. 2017. h Station, TX: StataCorp LLC (USA).

Results

The Median (Interquartile range) of registered cases during the understudied period in Iran was 133(362-83) cases per day. The minimum and maximum number of deaths during this period was 0 and 486 deaths per day. The highest number of deaths in Iran was recorded in November and early December 2020.

Figure 1 shows the trend of COVID-19 deaths from February 19, 2020, to February 5, 2021, in Iran. The starting point of the deaths of COVID-19 was estimated at 3.11 and the trend of new deaths increase significantly every day until November 24 2020 according to pre intervention slope of [(OR 1.14, 95% CI 0.96 - 1.32); P < 0.001]. The occurrence of new deaths had a decreasing trend after 24 November 2020 with a coefficient of [(OR -5.12, 95% CI -6.04 - -4.20); P < 0.001] (Tab. 1).

| Tab. I. Estimated coefficients of segmented regression model for new deaths of COVID-19 in Iran since February 19, 2020 to February 5, 2021. |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| New cases | Coefficients | Standard error | \(t\) | \(P\) | 95% confidence interval |
|-------------------------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Intercept | 3.11 | 10.84 | 0.29 | 0.77 | -18.22 - 24.44 |
| Pre intervention slope | 1.14 | 0.08 | 12.79 | < 0.001 | 0.96 - 1.32 |
| Chang in intercept | 39.13 | 25.50 | 1.53 | 0.12 | -11.03 - 89.50 |
| Chang in slope(interaction) | -6.26 | 0.47 | -13.09 | < 0.001 | -7.21 - -5.32 |
| Post intervention linear trend | -5.12 | 0.46 | -10.92 | < 0.001 | -6.04 - -4.20 |
EFFECT OF EPIDEMIC MANAGEMENT AND CONTROL PLAN ON COVID-19 MORTALITY IN IRAN: AN INTERRUPTED TIME SERIES ANALYSIS

Figure 2 shows the trend of COVID-19 deaths from February 19, 2020, to February 5, 2021, in the world. The starting point of the new deaths of COVID-19 was estimated at (2405.19), and the trend of daily new deaths was increasing before [(OR 18.66, 95% CI 14.41-22.92); P < 0.001] and after the 24 November 2020 [(OR 57.14, 95% CI 20.80-93.49); P: 0.002] (Tab. II). Figure 3 demonstrates that there was a significant and positive correlation (r: 0.31, p < 0.001) between number of new deaths of COVID-19 that occurred in the world and Iran since February 19, 2020, to November 24 2020. On the other hand, Figure 4 shows a significant but reverse Correlation between number of new deaths of COVID-19 that occurred in the world and Iran since November 24 2020 to February 5, 2021(r: -0.27, P: 0.01).

Discussion

RespondAny government must respond proactively in front of a pandemic, including the COVID-19 pandemic. The response, in this case, must include making policies to provide adequate personal protective equipment [12] and quick implementation of preventive measures such as lockdown, effective quarantine, social distancing, and screening, along with patient management and treatment [13, 14]. However, Iranian government has focused on gentle and without coercion measures to control the pandemic, rather than mandatory quarantine or lockdown [3]. In fact, for the Iranian government, which has been under the most severe economic sanctions in recent years, it is not even possible to implement a strict social distance program, let alone the government wants to enforce a complete lockdown or so-called stay-at-home policies, like what is done in some European countries [15].

From the early days of the COVID-19 pandemic, In Iran, a significant reduction in the number of new deaths due to COVID-19 has been observed in 2 weeks after the implementation of social distancing in the 4th

Tab. II. Estimated coefficients of segmented regression model for new death of COVID-19 in the world since February 19, 2020 to February 5, 2021.

| New cases               | Coefficients | Standard Error | t     | P > t  | 95% confidence interval |
|-------------------------|--------------|----------------|-------|--------|-------------------------|
| Intercept               | 2405.19      | 372.56         | 6.46  | < 0.001| 1672.42 - 3137.96       |
| Pre intervention slope  | 18.66        | 2.16           | 8.63  | < 0.001| 14.41 - 22.92           |
| Change in intercept     | 2462.09      | 714.63         | 3.45  | < 0.001| 1056.54 - 3867.65       |
| Change in slope (interaction) | 38.48    | 18.60          | 2.07  | 0.03   | 1.88 - 75.08            |
| Post intervention linear trend | 57.14 | 18.47          | 3.08  | 0.002  | 20.80 - 95.49           |
The present study results showed that Iranian COVID-19 epidemic management and control plan, which started on November 10, 2020, significantly reduced the number of COVID-19 deaths in Iran. The direct correlation between the number of deaths that occurred in Iran and the world before November 24, 2020, and the inverse correlation between the two after the date mentioned can also be a proof and confirmation of the results obtained (Figs. 3, 4). In fact, these figures show that before the mentioned date, the number of daily deaths in Iran has increased along with the number of deaths in the world, but after that date, while the number of deaths in the world has continued to increase, the number of deaths in Iran has decreased. Despite the economic and psychological impacts of the COVID-19 epidemic management and control plan and other preventive measures [15, 16], their role in containing the pandemic is undeniable. Some studies with ITS analysis approach reports significant effects of control measures on the COVID-19 mortality [3, 16‑19]. A study on 149 countries found that social distance measure reduced in 13% the COVID-19 morbidity [16]. Figueiredo et al. [17] reported a daily decrease of 7.88% in deaths, after the implementation of preventive policies in China. Siedner et al. [18], in the United States also showed a daily reduction in COVID-19 epidemic growth after the implementation of social distancing. Ghanbari et al. [3, 19] and also Alimohamadi et al reported a significant effect of preventive policies on COVID-19 mortality in Iran. One thing to note is that such success has been achieved without severe restrictions heavy fines. Another point is that this success was achieved despite the limited number of COVID-19 diagnostic tests (which also has economic reasons). Iran as a country with more than 84 million population, currently, is ranked 121th in the world and 6th (Last) in Persian Gulf region in terms of the number of tests per one million (with 112,305 tests /1 million population and more than 9 million tests population since the beginning of the pandemic [2]. However, COVID-19 mortality rate has been reported to be negatively associated with COVID-19 test number [20]. The current study had some limitations; during the study period, some variables such as people knowledge, attitude and practice about the disease, the criteria for the confirmed deaths. The accuracy of the diagnostic tests as well as the people’s compliance to health principles (such as using face masks, avoid attending gatherings and crowded places, etc), may be altered and this could affect the effectiveness of the preventive measures. Nevertheless, controlling the role of above-mentioned variables was not possible due to unavailability of data.

Conclusions

The Iranian COVID-19 epidemic management and control strategy reduced the mortality associated with COVID-19. Therefore, it is essential to continue these measures, in order to prevent the increase in the number of deaths.

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Ethical Statement

There is no ethical consideration of this study.

Conflict of interest statement

The authors declare that there is no conflict of interests.

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Authors’ contribution

YA and MS formulated the research questions, methodology, formal analysis, prepare drafts of the manuscript, review and editing. All authors have read and approved the final version of the manuscript.

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