Health Science Monitor
2025; 4(1): 46-52
Published online (http://hsm.umsu.ac.ir)

Original Article

Estimation of the reproductive number of COVID-19 in Iran and studying the role of health measures and social restrictions in changes of this index

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Abstract

***Background & Aims*:** The reproductive number of coronavirus disease 2019 (COVID-19) can reflect what level of health measures and social restrictions are needed to control the disease. Hence, this study was aimed to estimate the reproductive number of COVID-19 in Iran and study the role of health measures and social restrictions in changes of this index.

***Materials & Methods*:** In this study, the data required to estimate the reproductive number of COVID-19 was collected from 4372 people with COVID-19 referred to Dr. Masih Daneshvari Hospital in Tehran and also the statistics of the Ministry of Health of Iran. The role of health measures and social restrictions was also examined in changing this number.

***Results*:** Based on the study results, the reproductive number of COVID-19 was estimated to be about 2.75 in Iran. Considering a minimum of 10% and a maximum of 90% for the number of health measures and social restrictions, this number would be decreased from 2.48 to 0.28, respectively. Based on these results, the minimum rate of health measures and social restrictions to reduce the reproductive number of COVID-19 was 70% in Iran. At this level of health measures and social restrictions, the reproductive number of COVID-19 would be 0.82.

***Conclusion*:** Estimating the reproduction number of COVID-19 and studying the role of health measures and social restrictions on the changes in this number will provide an appropriate level of preventive measures to control the pandemic of this disease.

***Keywords*:** COVID-19, Epidemic, Health measures, Reproductive number, Social restrictions

Received 27 August 2024; accepted for publication 18 January 2025

Introduction

The coronavirus disease 2019 (COVID-19) pandemic, caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), was first identified in Wuhan, China, in December 2019. The virus rapidly spread across the globe, leading to the declaration of a public health emergency of international concern in January 2020. By March 2020, the outbreak was officially classified as a pandemic, impacting all inhabited continents and over 200 countries. By early 2021, the pandemic had resulted in more than 90 million confirmed cases and over 2 million deaths worldwide (1). Since the onset of the COVID-19, many studies have been conducted on its health indicators such as disease prevalence and mortality rate (2-5). But it is more important to estimate the reproductive number of this disease than studying health indicators (6). In fact, the disease reproductive number indicates the speed of infection transmission of the disease and is also a very good guidance to control COVID-19 and prevent its spread in different countries of the world (6-7). Although the reproductive number is a simple figure, it is an important numerical, usually displayed as R0 (8). The reproductive number is an indicator to measure the prevalence of a pathogen and is equal to the average number of people that any infected person can transmit the infectious agent to (9-10). For example, measles has one of the highest reproductive rates and each person can infect an average of 15 individuals in a community who are not immune (11).

The reproductive rate of the COVID-19 agent is estimated to be approximately 2.2 to 3.6 (9, 12-13). Although estimates vary from country to country, some studies have shown that the reproductive rate of the COVID-19 is higher than other similar diseases of the coronavirus family, such as SARS (14). Thus, although this virus is less dangerous in terms of mortality rate than other emerging viruses of the Corona family such as SARS and middle east respiratory syndrome (MERS), it has shown rapid transmission and special pathogenic behaviors that have made it very difficult to control (2, 5, 15). If the reproductive number of a disease is more than one, the number of cases increases exponentially, but if this number is less than one, the number of cases is not enough to continue the transmission of the disease and the disease gradually subsides (9-10). All countries affected by the COVID-19 pandemic are trying to reduce the prevalence of COVID-19 to less than one through health measures and widespread social restrictions (12, 16-18). The reproductive number of the COVID-19 is not the same in all countries and in each country according to the socio-economic structure is different (9, 12-13,19). Also, this figure is not a fixed number and changes under the influence of health measures and social restrictions (13). In fact, the reproductive number of the COVID-19 can be controlled by health measures and social restrictions. If α is considered the number of health measures and social restrictions to control the disease, the reproduction number of this disease can be controlled as follows:

$$R = R_0(1-\alpha)$$

For example, in this formula, α = 1 means taking complete health measures and imposing 100% restrictions in a community, and α = 0 means not taking health measures and not imposing social restrictions on disease control. Therefore, due to health measures by individuals in the community, as well as the application of social restrictions by the government, it is possible to reduce the number of COVID-19. But to determine what level of health measures and social restrictions is needed for this event requires estimating the reproductive number of the COVID-19 and studying the role of health measures and social restrictions in changing this number.

Materials & Methods

This cross-sectional study was conducted in order to estimate the reproductive number of the COVID-19 and study the role of health measures and social restrictions in changes of this index. Data collection was performed according to the daily statistics of the Ministry of Health and Medical Education in Iran as well as the information of 4372 confirmed patients with COVID-19 who have been referred to Dr. Masih Daneshvari Hospital in

Tehran from the onset of this disease. Dr. Masih Daneshvari Hospital is a university - affiliated and selected referral center for COVID-19 patients in Tehran, Iran. Based on this information, the role of health measures and social restrictions was also investigated on changes in the reproductive number of the COVID-19. In this study, STATA software version 14 was used to estimate the reproductive number of COVID-19 and achieve an appropriate level of health measures and social restrictions in order to control COVID-19 and reduce the number of patients with this disease.

In this study, the variables examined included the COVID-19 reproductive rate, which served as a quantitative dependent variable and an indicator of the pathogenicity of the infectious agent. This variable is influenced by health measures, prevention efforts, and social restrictions. Another variable examined was the level of social restrictions and health measures, defined as a proportional independent variable. This variable reflects the degree of adherence to health measures by individuals in the community and the extent of social restrictions imposed by the government. If we consider parameter α to represent the extent of social restrictions and health measures to control COVID-19, then $\alpha = 1$ indicates full implementation of these measures, while $\alpha = 0$ signifies the absence of any health measures or social restrictions to control the disease. Additionally, the time variable was considered a quantitative independent variable, representing the number of days since the onset of the COVID-19 pandemic.

It should be noted that the purpose of health measures is to pay attention to health issues such as the wearing of masks, gloves, regular handwashing with alcohol and detergents. The social restrictions imposed by governments can be named like the implementation of social distancing plans, closure of educational, cultural, and religious centers, reducing urban and interurban traffic, and telecommuting.

Results

Based on the results of this study, the prevalence of COVID-19 was estimated to be about 2.75 in a situation where no health measures and social restrictions considered to control COVID-19 in Iran (Table 1). This value is actually defined as the baseline of the reproductive number of COVID-19. This number would decrease with increasing the levels of health measures and social restrictions. Considering a minimum of 10% and a maximum of 90% for the level of health measures and social restrictions, the number of COVID-19 would decrease from 2.48 to 0.28, respectively (Table 1).

Table 1. Estimation of the COVID-19 reproductive number and the role of health measures and social restrictions in its variations

Level of health measures and social restrictions (%)	Estimation of the COVID-19 reproduction number	95% Confidence interval
0	2.75	(1.62 - 4.03)
10	2.48	(1.46 - 3.63)
20	2.20	(1.30 - 3.22)
30	1.92	(1.13 - 2.28)
40	1.65	(0.97 - 2.42)
50	1.38	(0.81 - 2.02)
60	1.10	(0.65 - 1.61)
70	0.82	(0.49 - 1.21)
80	0.55	(0.32 - 0.81)
90	0.28	(0.16 - 0.40)

According to these results, the minimum amount of health measures and social restrictions was 70% to reduce the reproductive number of COVID-19 and control the number of patients with this disease, in Iran. At this level of health measures and social restrictions, the reproductive number of COVID-19 was equal to 0.82, and in this case, the number of cases would not be enough to continue the disease transmission, and the disease gradually would subside over time.

Changes in the reproductive number of COVID-19 due to health measures and social restrictions will also change the trend of COVID-19 infection. As shown in Figure 1, the number of patients increased dramatically during a pandemic by increasing the reproductive rate of COVID-19 to more than one *(R* > 1) (Figure 1). Considering the value of 2.5 for the reproduction number of COVID-19 during 40 days from the beginning of the pandemic of this disease, the number of patients was about 100 thousand and during 60 and 80 days from the beginning of the pandemic, the number of patients was about 250 respectively. Also, 100 days after the onset of the COVID-19 pandemic, an increase of about 1.2 million was seen in the number of infected people. With the reduction of the reproductive number of COVID-19 to less than one ($R < 1$), although the number of patients increased during the pandemic, due to the decrease in the trend of the number of patients, there would not be enough conditions to continue the disease outbreak, and it was possible to control the COVID-19 pandemic (Figure 1).

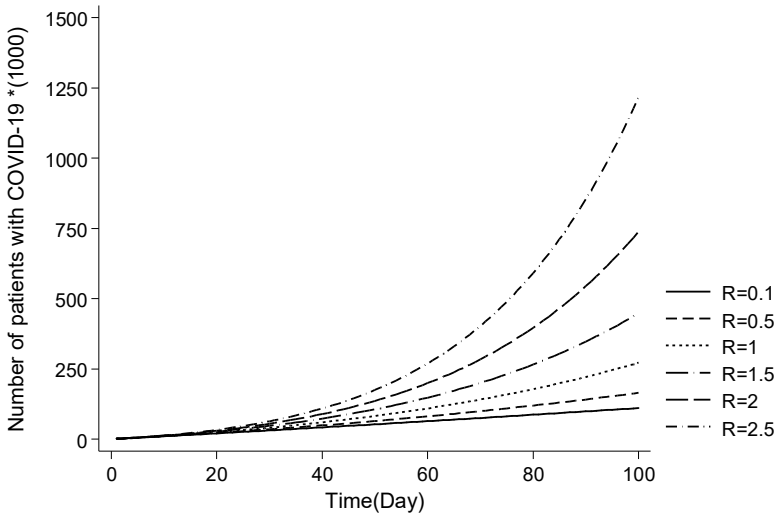

Fig. 1. Trend of increasing COVID-19 cases during the pandemic based on different reproduction number values

Discussion

Since the outbreak of the COVID-19 pandemic in China and its rapid spread to other countries, millions of people have been infected, and thousands have lost their lives (4-5, 15, 20). Numerous studies have been conducted on health indicators such as the incidence and mortality rates of COVID-19 (2-5). These studies estimate the mortality rate of COVID-19 to be less than 5% (4-5, 15). However, in some countries, the mortality rate has exceeded 10% (5, 20). Other studies indicate that the United States has been the hardest hit by the pandemic, accounting for a quarter of all cases and a third of deaths worldwide (21). Russia, Brazil, and the United Kingdom are the second to fourth most affected countries, respectively (22-23), followed by Spain, Italy, and Germany, ranked fifth to eighth (21-22).

More important than studying health indicators is estimating the number of infections (6). The number of COVID-19 infections is a crucial guide to understanding the speed of the disease's spread (6-7). When the number of infections exceeds one, conditions are ripe for a widespread pandemic, and the number of infected patients increases exponentially (9-10). The infection rate plays a decisive role in the spread of an infectious disease, with COVID-19 having an estimated infection rate of 2.2 to 3.6 (9, 12-13). Some studies have shown that COVID-19's infection rate is higher than other similar diseases caused by coronaviruses, such as SARS (14). The transmission rate of COVID-19, an indicator of the pathogenicity of the infectious agent, varies with health measures and social restrictions (13).

Among the infectious diseases, measles with a reproductive number between 12 and 18 is in the first place and MERS with a reproductive number of 0.3 to 0.8 is in the last place (11, 24). With the prevalence of COVID-19 in China and the transmission of the disease to other parts of the world, researchers have provided various estimates of the reproductive number of COVID-19 (9, 12-13, 25). The reproductive number of infectious diseases such as COVID-19 have different estimates under different socio-economic conditions and the extent to which people pay attention to health issues, hence a constant figure cannot be provided for it and must be separately estimated for every country (9, 12- 13). Therefore, some studies have estimated the reproductive number of COVID-19 between 1.4 and 3.8 (9, 25-26). Also, in some other studies, this number has been estimated between 2.2 to 3.6 (9, 12-13).

Based on the results of this study, the reproductive number of COVID-19 was estimated at about 2.75 in Iran, which is relatively a large number. This high number caused the number of COVID-19 patients to increase sharply and exponentially and caused a high prevalence and mortality rate. As the results of this study showed, the number of COVID-19 can be reduced to less than one by considering the level of health measures and social restrictions. According to the results of the present study, the appropriate level of health measures and social restrictions was at least 70% to reduce the reproductive number of this disease to less than one and finally to control the disease. Unfortunately, due to economic problems and people's lack of attention to health issues, it has not been possible to implement this level of health measures and social restrictions since the beginning of the outbreak of COVID-19 in Iran. However, unlike Iran, many countries of the world, especially developed countries have been able to reduce the reproductive number of COVID-19 to less than one, considering the high levels of health measures and social restrictions in a short time (7, 9, 13).

As shown in the results of this study, reducing the reproductive number of this disease causes the number of patients with COVID-19 to reach a level that reduces the likelihood of continuing the pandemic and as a result, the disease gradually subsides (9-10). However, in Iran, health measures and social restrictions have not been at a level that reduces the reproductive number of the disease to less than one. This has caused the country's health care system to face a shortage of manpower and medical equipment in the care of patients with COVID-19. Based on the results of this study, lack of proper implementation of health measures and social restrictions causes the health care system to face very complex and exhausting problems.

Even if it is not possible to implement this level of health measures and social restrictions in the long run, at least this level of health measures and social restrictions can be implemented in the country in a short period of time.

Creating a balance between the socio-economic structure of the country and the implementation of health measures and social restrictions at least 70% in controlling the pandemic of COVID-19 disease is very important and necessary.

Conclusion

Finally, it should be noted that the reproductive number of COVID-19 is not a constant number and each country has its own reproductive number according to socio-economic structures. This number also has a potential role in the recognition and transmission of COVID-19 and can guide researchers in achieving an

appropriate level of preventive measures to control COVID-19.

Acknowledgments

None declared by authors.

Author's Contributions

The authors confirm sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results. All authors read and approved the final manuscript.

Data Availability

The data supporting these findings are available from the corresponding author upon reasonable request.

Conflict of Interest

The authors have no conflict of interest in this study.

Ethical Statement

This study protocol was reviewed and approved by Shahid Beheshti University of Medical Sciences, with the approval number IR.SBMU.NRITLD.REC.1400.044.

Funding/Support

The Shahid Beheshti University of Medical Sciences financially supported this study.

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