

# Prediction the burden of COVID-19 in Iran: Application of disability-adjusted life years (DALYs)

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## Research Article

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# Abstract

**Background** The novel Coronavirus disease 2019 (COVID-19) rapidly became the world's largest threat to health and the economy in recent times. Prediction of the COVID-19 pandemic's full impact is a necessary gauge for future policy making, including resource allocation for prevention, mitigation, and control preparedness.

**Methods** We used the extended form of the Susceptible-Exposed-Infected/Infectious-Recovered/Removed (SEIR) model to predict new cases and number of deaths associated to COVID-19. Data from the Ministry of Health and Medical Education of Iran provided relevant parameters for predicting disability-adjusted life years (DALYs). We conducted a review of the literature on COVID-19-like diseases to develop disability weights (DWs) and convened an expert panel to verify their applicability. Beta-PERT distributions were used to calculate DWs for age groups. The minimum and maximum values were 0 and 0.14 for mild to severe disability, respectively.

**Results** The total DALYs for COVID-19 in Iran predicted by our model will be 973 per 100,000 populations from January, 2020 to January, 2021. Overall, 957 years per 100,000 will be from YLLs (98.4% of DALYs) and 16 will be from YLDs (1.6% of DALY). The total DALYs in men will be 1,082 years per 100,000 and 861 per 100,000 in women.

**Conclusions** Our predictions of COVID-19 burden will be useful in determining health priorities and to appropriately allocate resources to prepare for future outbreaks of COVID-19 and similar diseases. We hope this study will contribute to evidence-based health policy making in Iran.

## Background

In the course of last three decades, mortality and prolonged disability associated with emerging and re-emerging infectious diseases such as Severe Acute Respiratory Syndrome (SARS-CoV), Middle East respiratory syndrome (MERS-CoV), avian and pandemic influenza, Ebola virus disease (EVD) and Zika virus have had considerable impact on impact on health, the economy and society (1-3). Periodically, these diseases threatened survival in many populations. In December 2019, a novel Coronavirus subtype emerged in Wuhan (Hubei, China). On March 11, 2020, the World Health Organization (WHO) declared the novel coronavirus disease (COVID-19) a global pandemic (4). This virus appears more contagious and has more severe clinical presentation than either SARS-CoV or MERS-CoV (5). As of writing, there were over 25 million infected people and 854,772 deaths across 213 countries (6). The crisis has become the most devastating challenge in recent history. In Iran, the first case was diagnosed on 19 February 2020 (7) and through September 1, 2020, there were 375,212 confirmed cases and 21,571 reported deaths (8). COVID-19 may be responsible for the largest global burden of premature death and disability in 2020-2021.

Given the high incidence of COVID-19 and its potential burden of death and disease, it is necessary to obtain insight and information for decision making in health policy. Understanding the appropriate

amount of resources to allocate towards government health programs requires quantified measures of the burden of diseases to rank and prioritize the health threats requiring finite resources.

According to the global burden of disease (GBD) group, the proportion of DALYs for communicable diseases decreased in Iran from 1990 to 2017 (9). Nonetheless, communicable diseases are projected to remain a substantial burden in the near future. Meanwhile, COVID-19 has highlighted the potential resurgence of communicable diseases as a large share of overall health burden. COVID-19 is neither the first, nor likely the last, communicable disease of potential high morbidity and mortality. Therefore, it is critical to estimate the burden of this infectious disease in order to allocate the appropriate amount of resources and inform effective policy making in the post-pandemic era.

This study therefore predicted the burden of COVID-19 through disability-adjusted life years (DALYs) measure for Iran from January, 2020 to January, 2021. The burden of disease methodology, which was developed by the Harvard School of Public Health, World Bank and the World Health Organization (WHO), is appropriate approach to facilitate priority setting among diseases and comparing their relative disease burden (10-12). DALY were composed of two indicators: years of life lost (YLLs) due to premature mortality and years of life lived with disability (YLDs).

## Methods

### *Modeling Approach*

We describe our modeling approach in three steps: 1) Estimation of new cases and deaths, 2) Calculation of disability weights, and 3) DALY estimation.

#### 1. *Incidence/deaths*

To estimate new cases (incidence) and number of death, we used the extended form of the Susceptible-Exposed-Infected/Infectious-Recovered/Removed (SEIR) model (**Appendix, Figure A**), which is a dynamic compartmental mathematical modeling. The SEIR conceptual model is shown in **Figure 1**.

The *susceptible population* (In our model, we assumed the entire population as susceptible) and *exposed people* (which refers to individuals who are exposed to COVID-19 while they are asymptomatic and not yet infectious), will be become *infected* (referring to infected cases who demonstrate clinical symptoms after their incubation period and have the potential to transmit the disease to other susceptible individuals). Ultimately, depending on the severity of the disease, the infected cases will have one of the following four states:

1. Recovered and assumed to be immune from re-infection and no longer transmit the infection, or
2. Mild to moderate clinical symptoms while they follow home-isolation guidelines without requiring hospitalization,

3. Severe clinical symptoms and require hospitalization. Two probable outcomes are considered for this group of individuals such that they will be either recovered (and then discharged) or will not respond to the cares received (and then die), and
4. Death and removed from the model.

We considered a probable scenario for the percentage of self-isolation of the infected or symptomatic cases in response to the epidemic in Iran. This scenario is one of the most possible intervention of the health system, behavior change of the public, and containment strategies. The mean of the self-isolation rate was considered to be 10% from January 21 to February 17, 20% after the initiation of the epidemic from February 18 to March 18, 30% from March 19 to April 17, 40% from 18 April to 24 September 2020 and finally, 50% from September 25 to January 19, 2021. The parameters of this part analyzed based on a recent established national study (13) and extended for one year instead of four months. The effective contact rate was considered a time-varying state. We extracted the values considered for effective contact rate within 12 months (one year) of the COVID-19 epidemic stratified by different national models. The first model incorporated and maximum value for effective contact rate, assumed to be 13 in the national model in the early weeks of the epidemic and after the announcement of the epidemic by the officials the minimum value of contact rate was considered to 5. The descriptions of time date and calibrations input parameters are presented in recent established study (13). The value of effective contact rate are presented in **table 1 in Appendix**.

A Monte Carlo method was used to build the 95% uncertainty intervals (UI) around the point estimates of the expected numbers. We used the statistical distribution of a set of parameters obtained from both the literature review and expert opinion. In order to generate more precise and reliable estimation of model parameters, we did a calibration and depicted the number of simulated cases in contrast to reported actual data. Data were analyzed using Vensim DSS 6.4E software.

## **2. Disability weights**

A key variable for YLD estimation is disability weight (DW). The amount of DW should be obtained from a national survey of DW (14-16). However, a limitation for this analysis is the lack of morbidity data for COVID-19, which forced us to rely on estimates for relative weights attributed to similar health states. To the best of our knowledge, there has been no study on the DW of coronaviruses, therefore we convened an expert panel and focused on alternative health states (14-16). The expert panel included fifteen clinical experts with relevant experience in infectious and pandemic diseases. We asked participants to rate possible COVID-19 disability weight compared to selected similar diseases for different severity levels and age groups (i.e., mild, moderate, and severe). We considered the statistical distribution for DWs from the existing evidences and expert opinions.

## **3. DALY estimation**

This study provides a prediction for burden of COVID-19 by measured in DALY. DALY is the sum of YLL and YLD (Equation 1).

$$\text{DALYs} = \text{YLL} + \text{YLD} \text{ (Eq1.)}$$

We calculated the DALY using an incidence-based approach. The Coale and Demeny model life-table West was used to set the life expectancy table (10). The basic formula for YLLs is in Equation 2:

$$\text{YLL} = N \times L \text{ (Eq2.)}$$

N is the number of deaths due to the cause for the given age and sex in year; L is a standard loss function specifying years of life lost for death at age for sex (17). The estimation of YLD, which is calculated by multiplying the prevalence of disease by the disability weight, needs several parameters, including the number of deaths, incidence, age at onset, duration, and disability weight (DW) of COVID-19 (Equation 3).

$$\text{YLD} = \text{Prevalence of disease} \times \text{DW} \text{ (Eq3.)}$$

### ***Data Sources***

Given the scarcity of evidence on the magnitude of the outbreak and the burden of COVID-19 in Iran, the research team used multiple sources of data to estimate the burden of COVID-19 under a social distancing and isolation scenario. Social distancing control measures are policies that aim to minimize close contacts within communities and include individual-level strategies (e.g., quarantine, self-isolation) and community-level strategies (e.g., prohibitions on public gatherings, closing public facilities, especially schools, and non-essential businesses) (18).

Our prediction is based on all PCR-confirmed COVID-19 cases, in line with WHO recommendations. The age-gender distribution of confirmed cases and deaths up to June 19, 2020 was extracted from the Ministry of Health and Medical Education (MHME) of Iran through a secure line of access.

### ***Sensitivity Analysis***

To assess the impact of methodological choices (model and methodological uncertainty), such as the application of age weighting and the choice of the discount rate, we ran results under different scenarios for comparison. "Scenario analysis" is a type of multi-way sensitivity analysis (19), which can be used to identify the best scenario likely to appeal to decision-makers. From the economy and based on the concept that persons prefer benefits immediately rather than in the future, we can apply time discounting for future lost years of healthy life and age weighting (20, 21). We calculated DALY for COVID-19 based on four different social weighting scenarios. These were no age weighting or time discounting (A), age

weighing but no time discounting (B), no age weighting but 3% time discounting (C), and age weighting and 3% time discounting (D). These analyses were done by SPSS and Excel software packages.

## Results

The total DALYs for COVID-19 will be 973 years per 100,000 from January, 2020 to January, 2021 (**Table 1**). Overall, 957 years per 100,000 will be from YLLs (98.4% of DALYs) and 16 will be from YLDs (1.6% of DALY). The total DALYs in men will be 1,082 years per 100,000 and 861 per 100,000 in women.

The 70-79 year age group will have the highest DALYs at 5,945 DALYs per 100,00 and the 0-9 year age group will have the lowest at 92 DALYs per 100,000. The proportion of YLLs and YLDs in DALYs varied by age group. With increasing age, the proportion of YLLs increased for all groups except for the  $\geq 80$  year age group (**Table 1, Fig. 2**).

### *Incidence and deaths*

Our model predicts 3,650,000 COVID-19 cases (95% UL 296,590-16,323,060) and 44,150 deaths due to COVID-19 (95% UL 4,464-19,110) in Iran to 21 January, 2021.

### *Disability weight*

We considered beta-PERT distributions for DWs for each age groups. Overall, the minimum and maximum value was 0 and 0.14 for mild to severe, respectively. We approximate the UI by the 2.5% to 97.5% percentile range of DWs. The duration of COVID-19 disease was considered 14 days; that is, from infection to remission or death based on 85% of patients experiencing signs and symptoms for 14 days. Because they are not yet known for COVID-19, long-term sequelae were not included.

### *Sensitivity analysis*

**Table 2** shows calculated DALYs under four scenarios. The highest burden of 973 DALY was computed in A scenario with no age weighting and discount rate. The lowest burden of 499 DALY was computed in D scenario with age weighing and 3% discount rate.

As the use of age weighting and discounting can cause the differences in DALY, the above scenarios were applied. Based on development of DALY concept (17) and rarely used of age-weighting and discounting, we interpreted the COVID-19 DALYs with no time discounting and age weighting.

## Discussion

To our knowledge, this study is first to predict the burden of COVID-19 using a DALY method for Iran and low- and middle- income countries, where the burden of communicable diseases is high. The prediction of DALY for COVID-19 will be 794,226 in Iran through January 2021, translating the estimate of 973 healthy life years per 100,000. This prediction is based on the direct effects of COVID-19 on society. The possible

substantial indirect effects were not included in our model, including deaths due to a shortage of intensive care units, urban violence, crime, mental health issues, and suicide linked to the COVID-19 pandemic. We also project that the burden of COVID-19 is higher for men than women. Further, the largest volume of total DALYs will be in the 60-69 year age group and the lowest in the 10-19 year age group. However, the 70-79 year age group will be the highest DALYs per 100,000, followed by the 60-69 and  $\geq 80$  year age groups. Results demonstrate that elderly people bear a substantial and disproportionate burden of COVID-19, likely mediated through increasing age and increasing comorbidities with increasing age.

Our results are consistent with the future findings due to spread very quickly and infect many people in a short time. As there are at present no data in literature to had any initial estimates of how much the burden of pandemic COVID-19 is, we compared to other COVID-19-like diseases. Among COVID-19-like diseases, the DALYs of Zika virus and Ebola in global was 2244 and 503 in 2017 respectively. Another DALY estimation of pandemic was conducted in Netherlands which was estimated that 5,800 DALY (35 DALY per 100,000 population) were lost in 2009 caused by pandemic influenza A(H1N1) (22). Despite the genetic similarities, COVID-19 shows the clinical differences with other coronaviruses. Therefore, the DALYs of COVID-19 may not be comparable to other similar previous infectious diseases.

There are limitations and additional considerations for this study. First, some key parameters (e.g., hospitalization rate, incubation period, transmission probability) were from other countries or expert opinion. Second, instead of directly measuring associated health states of COVID-19 to calculate disability weights, severity weights for COVID-19-like diseases were used. The COVID-19 data have not been clear on the issue of severity because of long-term sequelae are still unknown. It will be necessary to follow cases over more time in the future. Third, as the quality of the DALY estimation depends on the quality of the data, we used MHME for age-gender distribution of the COVID-19 patients to June 19, 2020. These distributions may change over the period of our predictions.

Other considerations are needed to interpret our findings in the context: First, the economic disruptions caused by COVID-19 may result in lower-wage individuals having higher contact and triggering further infections disproportionately among those living in poverty. Second, a period of re-opening occurred in the months of Muharram and Safar with increased attendance at some mosques, holy shrines, and other social and religious gatherings that may affect the number of infections, hospitalizations, deaths, and other model parameters. Third, seasonal influenza viruses also circulate during the pandemic period, causing symptoms and illness similar to those seen with COVID-19, producing misclassification and under-counting of COVID-19 cases.

Countries at different levels of development may face differing burdens of disease. Health outcomes and indicators must match observed data and expected health outcomes. Some countries with middle-level social development index (SDI) may have worse than expected health outcomes in terms of number of infected cases, deaths, and DALYs. Outcomes for COVID-19 depend on people's risky and preventive behaviors. In Iran, a middle-level SDI country (23), the local governments make decisions to manage the spread of the infection.

The Covid-19 pandemic can be a reminder for all countries to emphasize the central component of sustainable development goals to improve health. DALY estimation of COVID-19 can help policymakers to identify new priorities, additional resources, and essential steps in response to new pandemic diseases. Health Adjusted Life Expectancy, Quality-Adjusted Life Year, and DALY can be used for broader national health coverage issues. For example, the better universal health coverage a country has the more positive effect is towards tackling emerging and re-emerging disease. For example, South Korea (24) and Singapore (25) have performed better during the COVID-19 and SARS pandemics. Therefore, COVID-19 is a wake up call to countries to take steps to increase overall public health coverage.

COVID-19 is a serious infectious disease, which unfortunately may not be unusual in the present and near future. In the recent past, the world has faced SARS, MERS, Ebola, and Zika. If we can build our experience with managing the coronaviruses outbreak, we will be better prepared to tackle others. Clearly, this current pandemic will not be the last. Coronavirus species appear to have a special infectivity potential, and more scientific resources should be devoted to reducing the severity of future epidemics.

## **Conclusion**

This study predicted DALY in Iran from January, 2020 to January, 2021 to emphasize the value of COVID-19 burden estimation for policymakers. Our prediction shows that, although there is a higher mortality among 60-79 years old, this pandemic almost is a disease with mild to moderate symptoms. Due to the unknown of many aspects of the COVID-19 outbreak, the disease burden of this pandemic was not comparable to the burden of recent outbreaks in Iran. With our study, we show a possibility to predict the disease burden of COVID-19 for allocating the resources and set effective strategies for national health plan. Better estimates of COVID-19 can also be achieved by actual data after the outbreak is over.

## **Abbreviations**

COVID-19: Novel coronavirus disease 2019; DALYs: Disability-Adjusted Life Years; DWs: Disability Weights; EVD: Ebola Virus Disease; GBD: Global Burden of Disease; LMICs: Low and Middle Income Countries; MERS-CoV: Middle East Respiratory Syndrome; MHME: Ministry of Health and Medical Education; SARS-CoV: Severe Acute Respiratory Syndrome; SDI: Social Development Index; SEIR: Susceptible-Exposed-Infected/Infectious-Recovered/Removed; WHO: World Health Organization; YLDs: Years of Life lived with Disability; YLLs: Years of Life Lost.

## **Declarations**

### **Ethics approval and consent to participate**

As the research is a prediction modeling study and does not involve human subjects, no ethical approval was required.

### **Consent for publication**

Not applicable.

## Availability of data and material

The datasets used and/or analyzed during the current study are available from the corresponding author on reasonable request.

## Competing interests

We have no conflicts of interest to disclose.

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## Tables

**Table 1.** Sex- and age- specific years of life lost (YLLs), years lived with disability (YLDs), and disability-adjusted life years (DALYs) lost due to COVID-19 in Iran.

| Category           | YLLs* (%)   | YLDs* (%) | DALYs* (%) |
|--------------------|-------------|-----------|------------|
| Total              | 957 (98.4)  | 16 (1.6)  | 973 (100)  |
| Sex                |             |           |            |
| Male               | 1065 (98.4) | 17 (1.6)  | 1082 (100) |
| Female             | 846 (98.3)  | 15 (1.7)  | 861 (100)  |
| Age group in years |             |           |            |
| 0-9                | 92 (100)    | 0 (0)     | 92 (100)   |
| 10-19              | 107 (97.7)  | 2 (2.3)   | 109 (100)  |
| 20-29              | 189 (96.4)  | 7 (3.6)   | 196 (100)  |
| 30-39              | 449 (97.6)  | 11 (2.4)  | 460 (100)  |
| 40-49              | 1094 (98.2) | 21 (1.8)  | 1114 (100) |
| 50-59              | 2454 (98.7) | 33 (1.3)  | 2487 (100) |
| 60-69              | 4595 (98.8) | 54 (1.2)  | 4650 (100) |
| 70-79              | 5845 (98.3) | 101 (1.7) | 5945 (100) |
| ≥80                | 2783 (97.4) | 74 (2.6)  | 2857 (100) |

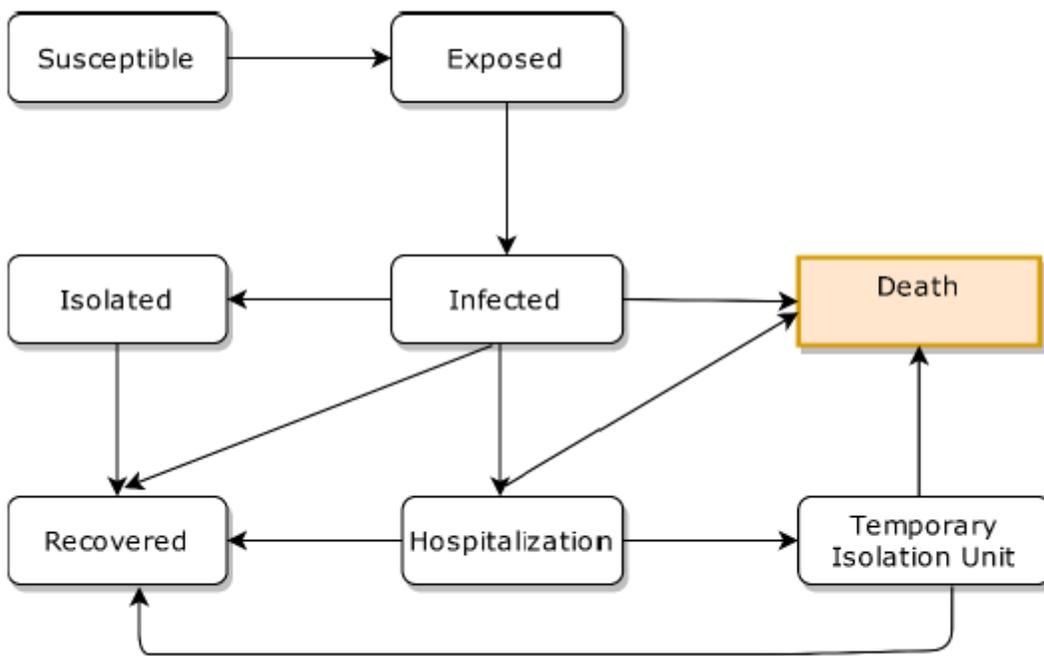
\*per 100,000 population

**Table 2:** YLL, YLD and DALY per 100,000 for COVID-19 under scenarios of different social values, Iran.

| Scenario | Age weighting | Discount rate (%) | YLL | YLD | DALY |
|----------|---------------|-------------------|-----|-----|------|
| A        | No            | 0                 | 957 | 16  | 973  |
| B        | Yes           | 0                 | 682 | 15  | 697  |
| C        | No            | 3                 | 677 | 16  | 693  |
| D        | Yes           | 3                 | 484 | 15  | 499  |

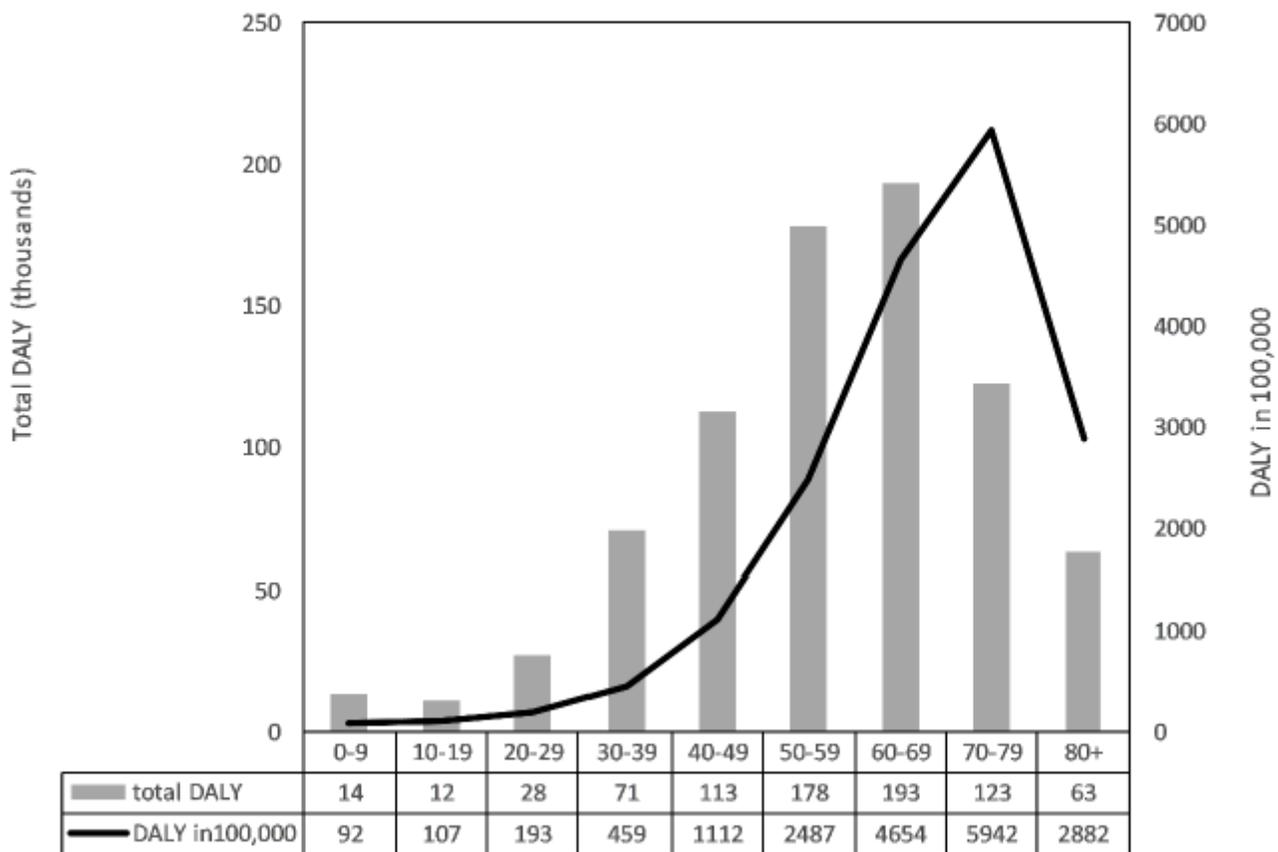
YLLs, years of life lost; YLDs, years lived with disability; DALYs, disability-adjusted life years.

## Figures



**Figure 1**

The SEIR conceptual model from susceptible to recovery or death.



**Figure 2**

Total DALYs and DALYs per 100,000 individuals for COVID-19 according to age groups, Iran.

## Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- [Appendix.pdf](#)