Mediterranean BioMedical Journals
Integrative Journal of Medical Sciences
2020, Volume 7, ID 170
DOI: 10.15342/ijms.7.170

RESEARCH ARTICLE

Prediction of COVID-19 Dynamics in Kuwait using SIRD Model

Ahmad Sedaghat* [1], Fadi Alkhatib [1], Negar Mostafaeipour [2], Seyed Amir Abbas Oloomi [3]

[1] School of Engineering, Australian College of Kuwait, Safat 13015, Kuwait
[2] Medical school, Rafsanjan University of Medical Sciences, Rafsanjan, Kerman, Iran
[3] Department of Mechanical Engineering, Yazd Branch, Islamic Azad University, Yazd, Iran

ABSTRACT
COVID-19 infectious started on 24 February 2020 with 5 patients returning to Kuwait. The ministry of health (MOH) has reported the total of 26,192 patients with 10,156 recovered, 15,831 under treatment, 205 deceased, 206 critical and 23 quarantined in Kuwait on 30 May 2020. A rough prediction of number of expected infected patients, patients under treatment, patients in critical condition, and death will assist health authorities for better planning and the government policy makers a better approach to reduce the number of susceptible people to COVID-19. In this study, a modified SIR model is used to determine COVID-19 dynamics in Kuwait. COVID-19 data for 97 days consist of infectious, recovered, and deceased cases are used to study SIRD model and to obtain the re-production number (R_0) and the total susceptible (Sus) population. The accuracy of the fitted model is assessed using the coefficient of determination (R^2). The re-production of R_0=4.7 with the total susceptible (predicted) population of 123,102 is obtained to assess dynamics of COVID-19 in Kuwait. It is predicted that the peak of COVID-19 infectious will be around 23 June 2020 with the total infected cases of 56,533. However, maximum 26,039 people on need of hospitals may be accelerated on 10 June 2020 and will quickly drop on 2 July 2020 to only 377 people. The total deceased cases will be 1,169 on this date; although, the death tolls may continue to the total value of 2,667 by the end of pandemic.

KEYWORDS: COVID-19; Corona Virus; Dynamics; Kuwait; SIR model.

Correspondence: Ahmad Sedaghat, School of Engineering, Australian College of Kuwait, Safat 13015, Kuwait
E-mail: a.sedaghat@ack.edu.kw

INTRODUCTION

The novel corona virus (COVID-19) was first observed in a seafood centre in Wuhan, China in December 2019. China confirmed 78,824 infectious cases on 28 February 2020 with 2,788 death tolls in the country. Soon after, it is announced the COVID-19 infectious as the pandemic with some 51 countries reported cases of COVID-19 in their countries [1, 2].

The ministry of health (MOH) in Kuwait reported the first 5 infected cases with COVID-19 On 24 February 2020 from travellers to Kuwait [3]. Kuwait government have taken several steps as time passed to control the pandemic. These practices are included with closure of all education system from schools to Universities, closure of all public gathering places from restaurants, sport centres to leisure clubs, ceased operation of all public transportation from taxis to buses, partial curfew banning people leaving home from 6:00 PM to 8:00 AM, partial lockdown on certain areas such as Mahboula and Jleeb Al Shuyoukh with 2 hours from 4:30 PM to 6:30 PM break, and full lockdown of Kuwait to retard speed of COVID-19 transmission and delay the peak of infection. From 24 February to 30 May 2020, the cumulative infected cases are reported 26,192 with 1,073 as peak number per day on 19 May 2020. The total recovered cases are reported 10,156. On 30 May 2020, the total under treatment are announced 15,831, the total death tolls of 205 case, and the total of 206 in critical condition [3].

Prediction of dynamics of a pandemic is crucial for the governments and health organizations to have better understanding of the situation. Several simple models such as Gompertz, Bertalanffy, and Logistic models have been studied [2] which are useful for predicting the total number of infected cases

by the end of pandemic. Many researchers suggested that the SIR model is the best among other models for epidemiology predictions [1, 2, 4].

In this paper, we have used a modified SIR model to give more useful clinical information such as number of patients under treatment, number of deceased cases, in addition to the total infected and recovered cases. The goodness of fit of the studied model for COVID-19 data are examined using the coefficient of determination (R^2). Results of COVID-19 dynamics are presented and discussed for Kuwait population. Predictions for peak and end of COVID-19 pandemic in Kuwait with dates and numbers are presented and conclusions are drawn.

METHODOLOGY

SIRD Model

To model COVID-19 pandemic, a mathematical model is required to tackle fast exponential growth of the pandemic. The SIR model is widely used in epidemiology as an efficient mathematical tool for prediction of dynamics of infectious disease. The SIR model was introduced by Kermack andMcKendrick [5] for prediction of growth rate of contagious diseases and applied in plague and cholera epidemies. The SIR model consists of 3 set of ordinary differential equations (ODE) based on susceptible (Sus) cases, infected cases (Inf), and removed cases (Rem) including recovered and death [6, 7].

Recent COVID-19 events in countries such as Italy and USA urge to predict temporal growth of people under treatment (UT), death tolls, and people who need ventilators. Therefore, we modified SIR model to include one additional equation on number of deceased (Dec) cases. Hence, SIR model given in [8] is modified as follows:

$$\begin{aligned} \dot{Sus} &= -\frac{\beta}{N} Inf.Sus \\ \dot{Inf} &= \frac{\beta}{N} Inf.Sus - (\gamma_R + \gamma_D) Inf \\ \dot{Rec} &= \gamma_R Inf \\ \dot{Dec} &= \gamma_D Inf \end{aligned} \quad \textbf{(1)}$$

In equation (1), *Sus* is the susceptible population, *Inf* is the infected population, *Rec* is the recovered population, and *Dec* is the deceased population. The dotted parameters are time derivatives; e.g. $\dot{Sus} = dSus/dt$. The transmission rate β, the recovery rate γ_R, and the death rate γ_D should be determined by fitting SIR model with COVID-19 data. The removing rate is obtained by $\gamma = \gamma_R + \gamma_D$.

The important re-production number $R_0 = \beta/\gamma$ is a measure of expected new number of infectious which expresses the number of new people susceptible to infectious by the patient. Hence, we propose to determine the number of susceptible populations in SIR model as follows:

$$Sus = R_0.Inf \quad \textbf{(2)}$$

The total population *N* is a fixed number and is defined by:

$$N = Sus + Rec + Inf + Dec = constant \quad \textbf{(3)}$$

The total infected patients can be obtained as follows:

$$TI = Inf + Rec + Dec \quad \textbf{(4)}$$

A set of initial conditions are applied to solve the set of ODE equations (1) of SIR model such as follows:

$$Sus(0) = 80{,}000;\ Inf(0) = 5;\ Rec(0) = 0;\ Dec(0) = 0 \quad \textbf{(5)}$$

The modified set of SIR model equations (1) are solved with initial conditions such as equations (5) using MATLAB. Kuwait has a population around 4,270,571 based on Worldometer 2020 [9]. However, the correct initial susceptible population can be found using simple models or with the re-production number in SIR model if sufficient data is available.

GOODNESS OF FIT TECHNIQUE

The coefficient of determination

The coefficient of determination (R^2) is widely used method on goodness of fit when predicted variables are compared with actual data particularly for situations that future outcomes are sought. The coefficient of determination (R^2) evaluates the predicted values (y) against actual data (x) as follows [10]:

$$R^2 = 1 - \frac{\sum(x-y)^2}{\sum(x-\bar{x})^2} \quad \textbf{(6)}$$

In equation (6), $\bar{x}$ is the average of collected data values. Better fitted functions provide R^2 value close to unity.

Results of SIRD Model

SIRD model is applied for an arbitrary initial susceptible population size of 80,000 to determine the re-production number R_0. The reproduction number R_0 is then used to determine the correct susceptible population and the procedure continues to reach a converged solution.

Initial Susceptible Population

Results for the parameters in SIRD model are obtained for an initial arbitrary population size of 80,000 as listed in Table 1. Then the re-production number R_0=5.854 is obtained. Considering the total infectious population of 26,192 on 30 May 2020 and the re-production number R_0=5.854, the predicted susceptible population in Kuwait is determined using equation (2) as follows:

Predicted total susceptible population=5.854×26,192 =153,319

The predicted total susceptible population of 153,319 is used next to predict COVID-19 dynamics in Kuwait. As observed in Table 1, the new re-production number R_0=4.699 is obtained. Repeating one more time with the re-production number R_0=4.699 as follows:

Predicted total susceptible population=4.699×26,192 =123,102

With the new predicted susceptible population of 123,102, the converged re-production number R_0=4.699 is obtained with better R^2 residuals as seen in Table 1.

Predicted Susceptible Population

The total susceptible (predicted) population of 123,102 are applied in SIRD model using the model parameters given in Table 1. Figure 1 shows that 3 set of COVID-19 data including infected, recovered, deceased are simultaneously fitted with SIRD curves. Goodness of fit (R^2) values are shown in Table 1. The re-production number was converged in just two iterations as shown in Table 1.

Table 1: Parameter values of SIRD model for the predicted COVID-19 in Kuwait

Susceptible population	Transmission rate (β)	Recovery rate (γ_R)	Death rate (γ_D)	Removing rate (γ)	Reproduction number (R_0)	$R^2(I)$	$R^2(R)$	$R^2(D)$
80,000	0.12	0.02	0.0005	0.0205	5.854	0.9842	0.9598	0.9679
153,319	0.1225	0.0255	0.00057	0.02607	4.699	0.9556	0.9704	0.9563
123,102	0.1225	0.0255	0.00057	0.02607	4.699	0.9721	0.9746	0.9596

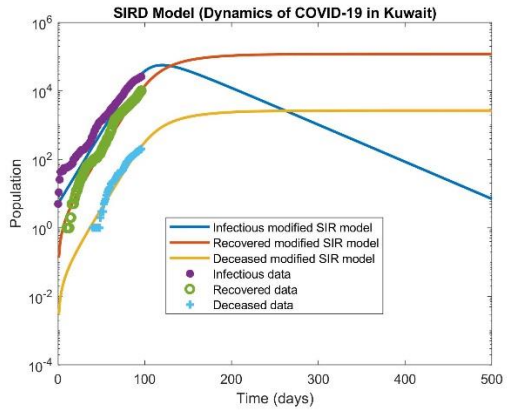

Figure 1: Fitting 3 set of COVID-19 data simultaneously with SIRD model for the total susceptible population of 123,102 in Kuwait (30 May 2020).

Figure 2 shows the dynamics of COVID-19 pandemic in Kuwait for susceptible, infected, recovered, deceased, and total infected populations. Important dates including 25 June 2020, the peak of infectious are summarized in Fig. 3.

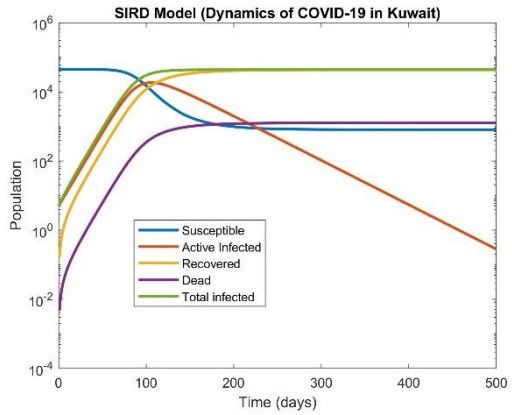

Figure 2: Dynamics of COVID-19 in Kuwait using SIRD model (30 May 2020).

As shown in Fig. 3 on 23 June 2020 at the peak of COVID-19 in Kuwait, we may reach to the total infected cases of 56,533 in Kuwait with earlier maximum hospital treatment of 26,039 people on 10 June 2020. The need of hospitalization may drop immediately by 2 July 2020 to only 377 people with the total deceased of 1,169 on this date; although, the trends in Fig. 3 shows that the death toll may continue to the total value of 2,667 by the end of pandemic (not shown here).

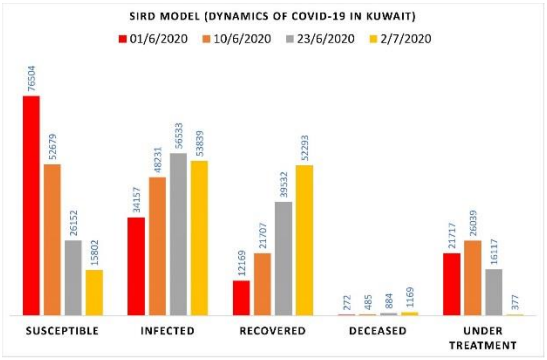

Figure 3: Important dates with numbers of susceptible, infected, recovered, deceased, and under treatment of COVID-19 in state of Kuwait (30 May 2020).

CONCLUSIONS

This paper has applied a modified SIR model to track simultaneously 3 set of COVID-19 data including infected, recovered, and deceased to find better prediction of COVID-19 dynamics in Kuwait. From the results of this study, it is concluded that:

- SIRD model predicts well the occurrence of the peak of COVID-19 infectious regardless of the total susceptible population.
- SIRD model can simultaneously fit 3 set of COVID-19 data including infected, recovered, and deceased.
- The re-production number (R_0) of 4.699 is found for the total susceptible population of 123,102 in Kuwait.
- The peak of infectious curve is expected around 23 June 2020 with the maximum cumulative infectious cases of 56,533 in Kuwait.
- The total active infected cases will reach 26,039 around 10 June 2020 whilst it will quickly drop to 377 cases on 2 July 2020 in Kuwait.
- The total number of deceased patients may reach to 2,667 cases by the end of pandemic in Kuwait.

SIRD model is a handy method works well with epidemiological data and may give good insights particularly for peak days of infection and is recommended for studying COVID-19 in different countries.

COMPETING INTERESTS

The author received no funding and has no conflict of interest to declare.

REFERENCES

[1] Huang Y, Yang L, Dai H, Tian F & Chen K. Epidemic situation and forecasting of COVID-19 in and outside China. [Submitted]. Bull World Health Organ. E-pub: 16 March 2020. DOI: 10.2471/BLT.20.255158.

[2] Lin Jia, Kewen Li, Yu Jiang, Xin Guo, Ting zhao, Prediction and analysis of Coronavirus Disease 2019, arXiv:2003.05447v2, arXiv 2020.

[3] COVID-19 updates, State of Kuwait live [Internet]. [cited 2020 May 27]. Available from: https://corona.e.gov.kw/En/

[4] Roda WC, Varughese MB, Han D, Li MY. Why is it difficult to accurately predict the COVID-19 epidemic? Infect Dis Model. 2020 Jan 1;5:271–81. DOI:10.1016/j.idm.2020.03.001

[5] Devore JL. Chapter 12.5: Simple Linear Regression and Correlation (pp. 508–510). Probability and Statistics for Engineering and the Sciences . 8th Edition. Boston, MA: Cengage Learning. 2011. ISBN 978-0-538-73352-6.

[6] Kermack WO, McKendrick AG. A contribution to the mathematical theory of epidemics. Proc R Soc London Ser A, Contain Pap a Math Phys Character. 1927 Aug 1;115(772):700–21. DOI: 10.1098/rspa.1927.0118

[7] Anderson RM, May RM. Population biology of infectious diseases: Part I. Vol. 280, Nature. Nature Publishing Group; 1979. p. 361–7. DOI: 10.1038/280361a0

[8] Jones DS, Sleeman BD. Ch. 14 in Differential equations and mathematical biology. London: Allen & Unwin, 1983.

[9] Kuwait Population (2020) - Worldometer [Internet]. [accessed 2020 May 27]. Available from: https://www.worldometers.info/world-population/kuwait-population/.

[10] Hethcote HW. The mathematics of infectious diseases. SIAM review. 2000;42(4):599-653. DOI: 10.1137/s0036144500371907.