Determination of the Course of COVID-19 Pandemic Using Modified Mathematical Modeling

Original Research Paper

Abstract

Introduction: COVID-19 appeared in China at the end of 2019. It then spread all over the world very quickly. The new type of corona virus COVID-19, which causes respiratory tract infection, is destructive with its high rate of transmission and mortality rate

Aim: In this study, previously applied to literature in Turkey and Iran, to determine the course of epidemics with the help of a specially modified mathematical modeling to calculate the course of the pandemic in Afghanistan and COVID-19 is intended to reveal.

Method and Results: If the normal course of the disease continues, the number of cases after 4 months is expected to reach the limit of 135,000. However, depending on the severity of increasing public, social and individual measures, it is predicted that the total number of cases may fall below 100,000. If the disease continues to spread in its current form, it is possible to reach more than 2000 new cases daily by reaching the maximum level, like the end of June-early July. However, it is understood from the graph that this number will fall much further if the measures are followed.

According to our modified mathematical modeling results, the COVID-19 pandemic will spread very rapidly in Afghanistan. However, it is possible to reduce the number of cases and deaths very effectively with easy measures.

Keywords: COVID-19, pandemic, mathematical modelling, Afghanistan.

Introduction

COVID-19 appeared in China at the end of 2019. It then spread all over the world very quickly. The new type of corona virus COVID-19, which causes respiratory tract infection, is destructive with its high rate of transmission and mortality rate. The World Health Organization has declared a pandemic due to COVID-19. All countries are working to predict the course of the COVID-19 pandemic, the number of possible cases and deaths, and to take action. Afghanistan is a large Asian country with a population of over 30 million. The first case of COVID-19 in Afghanistan originated from Iran in terms of contamination [1, 2]. The course of epidemic diseases can be determined with modified mathematical modeling. It can also be calculated how many measures can be taken, how much the number of cases and deaths can be reduced [3, 4]. In this study, previously applied to literature in Turkey and Iran, to determine the course of epidemics with the help of a specially modified mathematical modeling to calculate the course of the pandemic in Afghanistan and COVID-19 is intended to reveal.

Material-Methods

In the literature, for a region with a population P (city, country), it is stated that "the time-dependent change (spreading) rate of the M; number of individuals who have caught a contagious disease is proportional to the multiplication ofthe numbers ofthose who have caughtthe disease and those who have not" [5]. The mathematical model of this situation is given by the following differential equation,

$$\frac{dM}{dt} = \delta M(P - M), \tag{1}$$

where, δ is the positive proportionality constant.

The population distribution, socio-economic situation, social reflexes, individual sensitivities, public health service delivery quality and individuals' level of access to health services vary. Therefore, in creating a model for the course of the disease, in addition to the initial conditions, it requires improvements to accommodate these situations. In this study, the model above was revised specifically for the "corona pandemic" and discussed in the form of "the spreading rate of the disease; is directly proportional with the multiplication of the numbers of those who have caught the disease and those who have not, and inversely proportional with the time-variable".

Meanings corresponding to used variables and parameters were as given follows:

t: Independent time variable in units of days,

δ: A parameter that covers all factors that influence the spreading rate.

$M(t)$: Dependent variable expressing the number of patients at the time t,

$\frac{dM}{dt}$: Derivative corresponding to the time-dependent change (spreading) rate of the disease,

Let the initial ($t = 0$) number of patients be $M(0) = M_0$, the number of patients at a time $t = t_1$ be $M(t_1) = M_1$ and the number of individuals who are open to the disease be P. The purpose of the study is, Based on real case and death data from April 1 to May 5, 2020; to determine the course of COVID-19 pandemic in Afghanistan in May, June, July and August. In the model given in (1), to take the right-hand side as a function of the time variable t, and with the help of a modified mathematical model to be more compatible with actual data, to obtain more reliable data regarding the course of the disease in the progression of time. For this, by using the expression $\delta = \delta(t) = 0.9k/\sqrt[10]{t}$ dependent on the t-time variable instead of the constant δ on the right-hand side, we are proposing the following initial value problem (IVP) related to the issue as,

$$\frac{dM}{dt} = \delta M(P - M), \qquad M(0) = M_0\,, \;\; M(t_1) = M_1 \tag{2}$$

Here, k is a positive proportional constant. The solution of the problem (2) will provide a formula related to how many people could get sick after how many days, that is, a time-dependent analytical function in units of days. Firstly, solving the differential equation in the separable variables type, we get

$$\frac{dM}{dt} = \frac{0.9k}{\sqrt[10]{t}} M(P - M) \Rightarrow \frac{dM}{M(P-M)} = \frac{0.9k}{\sqrt[10]{t}} dt$$

$$\Rightarrow \frac{1}{P}\int \left(\frac{1}{M} + \frac{1}{(P-M)}\right) dM = 0.9k \int t^{-1/10} dt$$

$$\Rightarrow ln\frac{M}{P-M} = Pkt^{0.9} + lnc$$

$$\Rightarrow M(t) = \frac{Pc}{\left(e^{-Pk\,t^{0.9}} + c\right)}\,. \tag{3}$$

Applying the initial condition, we have,

$$M(0) = M_0 = \frac{Pc}{(e^0 + c)} \Rightarrow c = \frac{M_0}{P - M_0}\,. \tag{4}$$

Now, using $M(t_1) = M_1$, let's determine the k −parameter,

$$M(t_1) = M_1 = \frac{Pc}{\left(e^{-Pk\,t_1^{0.9}} + c\right)}$$

$$\Rightarrow -Pk = -t_1^{-0.9} ln\left(\frac{M_1}{c(P - M_1)}\right). \tag{5}$$

Lastly putting (4) and (5) into (3), we obtain the analitical solution of given IVP (2) like as,

$$M(t) = \frac{Pc}{\left(c + e^{-r\,t^{0.9}}\right)}, \qquad (6)$$

where, $r = t_1^{-0.9} ln\left(\frac{M_1}{c(P-M_1)}\right)$.

Results

Here, we give a detailed analysis the course of COVID-19 pandemic for next 4 months in Afghanistan. For this aim, we take the potential number of individuals open to getting the disease is P=140000. We chose the date 01 April 2020 as $t = 0$, $H(0) = H_0 = 237$ patients; $t_1 = 35$ as 05 May 2020 with $H(t_1) = H(35) = H_1 = 3224$ patients, let us assess the figure below where we may observe the behavior of the spread (approximate number of cases) in a 120-day future time interval ahead of us.

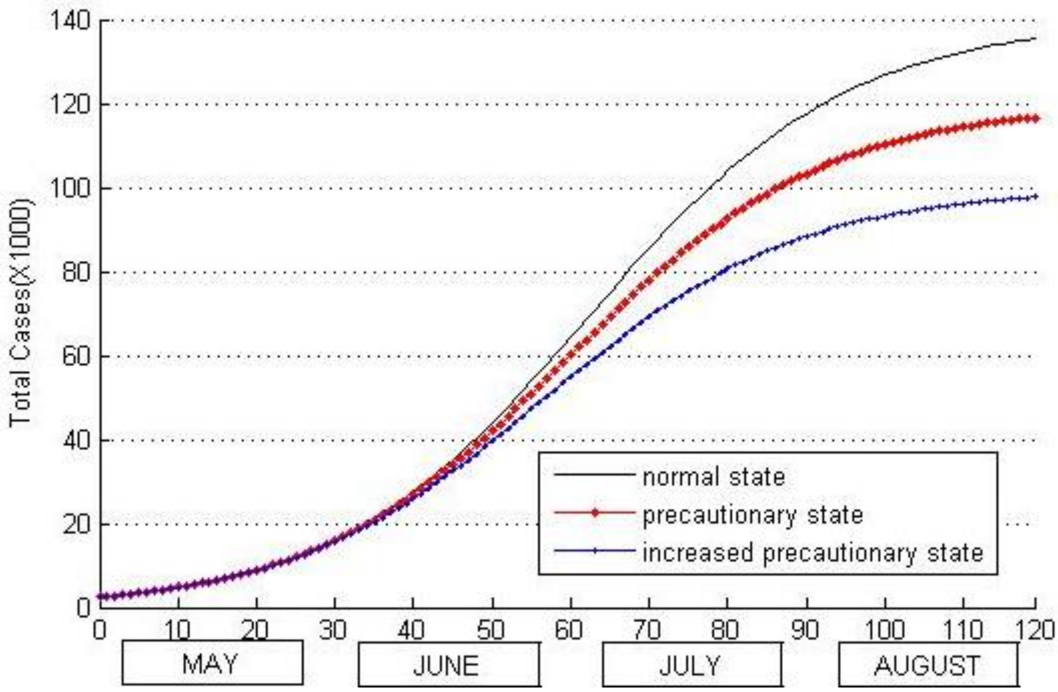

Figure 1: Changing of total cases in the next 4 months.

If the normal course of the disease continues, the number of cases after 4 months is expected to reach the limit of 135,000. However, depending on the severity of increasing public, social and individual measures, it is predicted that the total number of cases may fall below 100,000. We presented our findings on daily case numbers in the chart below.

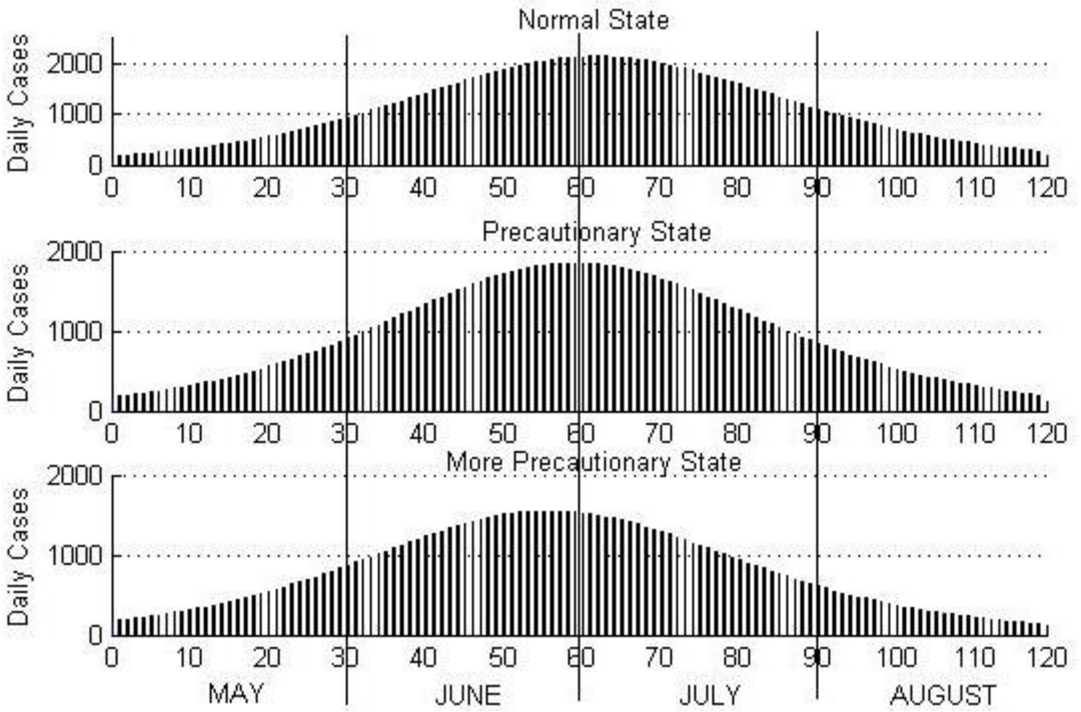

Figure 2: Changing of daily cases in the next 4 months.

If the disease continues to spread in its current form, it is possible to reach more than 2000 new cases daily by reaching the maximum level, like the end of June-early July. However, it is understood from the graph that this number will fall much further if the measures are followed. These numbers guide us on what equipment public hospitals should have in terms of personnel, physical and technical facilities during healthcare delivery.

Our findings regarding the total number of deaths (Figure 3) and daily deaths (Figure 4), which are formed by taking into account that the total Death-Case ratio, which was around 0.03 on 5 May, will increase some more in the future, is given below.

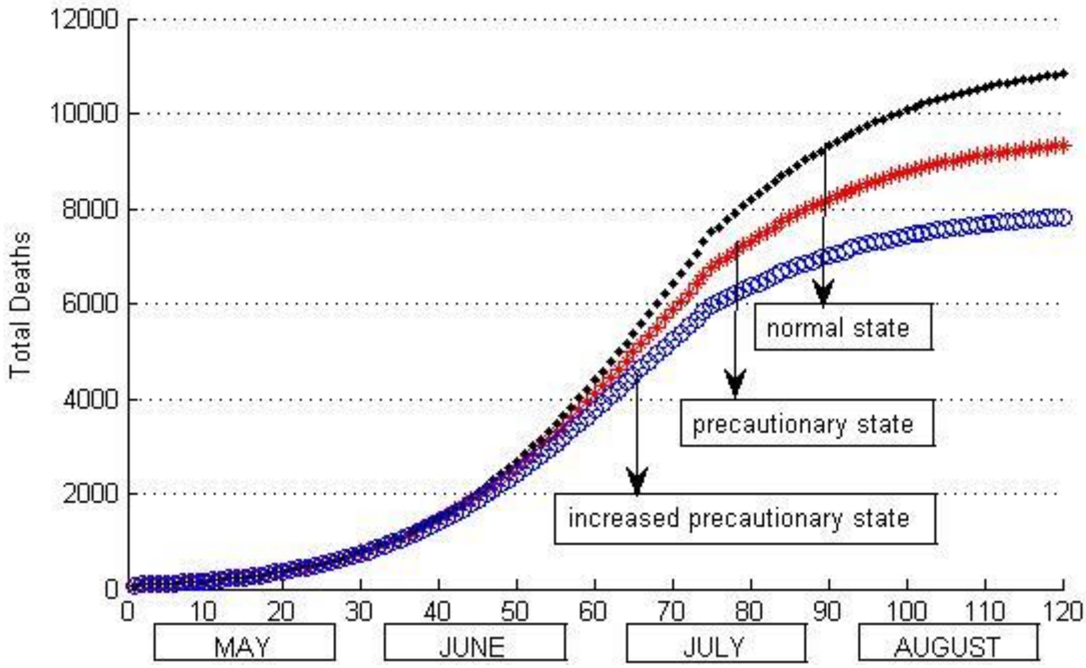

Figure 3: Changing of total deaths in the next 4 months.

Depending on the severity of the implementation of the measures according to the figure and the quality of the hospital services, it is understood that the deaths may occur below 8000. Otherwise, we may encounter a picture where more than 11000 people died after 4 months due to COVID-19.

Finally, let's consider the following figure, which includes data on daily deaths.

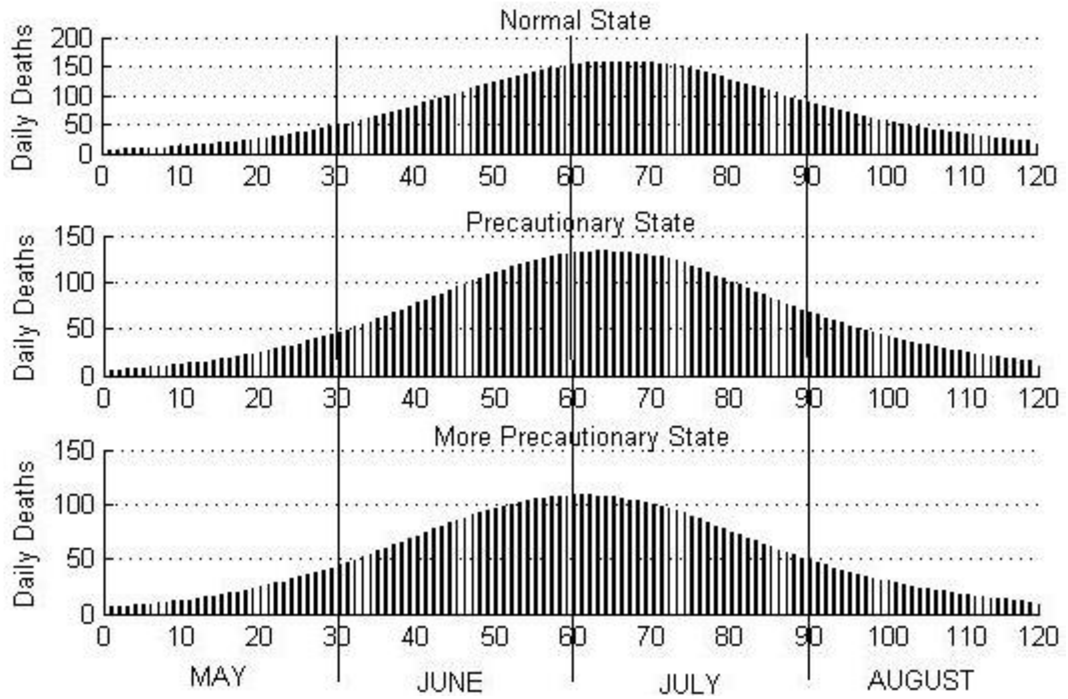

Figure 4: Changing of total deaths in the next 4 months.

Daily deaths are expected to reach the maximum level at the beginning or mid-July of the day, when around 150 people die. Let's not forget that following the measures seriously, eating healthy and natural, and getting a good treatment will lower these numbers much more.

Discussion

In Afghanistan, the first case of COVID-19 was detected on 24/2/2020. Within 66 days, it has been spread all over 34 provinces, and has reached a total number of 2171 positive cases with a death toll of 64. The national testing centers are only five, with a recently improved capacity of not over 200 tests per day each. That is why the total number of performed tests is only 1022 so far. The people who may have international contact reach an estimated number of 180,000. Due to having porous borders with and four million refugees in the neighboring countries of Iran and Pakistan, who are repatriating 18,000-20,000 Afghan nationals every day, which are barely screened for COVID-19 symptoms, the number of high risk people for disease transmission is fierce. Iran has been the first and most infected country in the region, with a daily repatriation program of 15,000 afghan nationals, there is a real possibility of having similar prevalence in Afghanistan in a matter of next 2-3 weeks. With a majority of population living in poverty, and illiteracy; Afghanistan is unable to extend its 2-week partial lock down which reaches its end after 4 days, and may have to embrace the wave of infection spread freely in the population. That may be the reason of starting a governmental project of digging mass graves at the periphery of major cities, and official announcement of getting ready for 125,000 fatalities in the capital city of Kabul only (which has an estimated population number of 5.5 million). Meanwhile, governmental officials state epidemiological studies which says that for acquiring a sufficient herd immunity against COVID-19, at least 50% of the population should survive infection or get vaccinated; and assure people that the wave may establish herd-immunity and will stop the spread of infection within 4 months, which seems to be earlier than the world could mass-produce any possible vaccine. If such a policy for acquiring herd-immunity is really undertaken, the least that can be done for reducing fatalities and saving the susceptible people who will really benefit from the expected vaccine; isolating the elderly (over 60) which make up only 4.3% of the total population and individuals with comorbidities may be the only option.

Conclusion

According to our modified mathematical modeling results, the COVID-19 pandemic will spread very rapidly in Afghanistan. However, it is possible to reduce the number of cases and deaths very effectively with easy measures. Our numerical results reveal the necessity of the measures to be taken. It is necessary to pay attention to cleanliness and individual hygiene. It would be beneficial to maintain physical distance and apply effective isolation. For a good immunity, it is necessary to pay attention to natural and healthy nutrition, not to gain weight, increase mobility.

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