COVID-19 Flattening Curve,"A Recipe for Second Wave of Infections in Kenya"

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Abstract

Background: COVID-19 disease has persisted since it was declared a global pandemic by World health organization (WHO) in February 2020. Kenya had notified a total of 34,057 cases, reported 574 deaths by end of August 2020. The Country's positivity rate had also come down from 13 to 4 percent between June and August 2020. Despite the gains in controlling the first COVID-19 wave from the non-pharmaceutical interventions, most countries would not sustain the economy with prolonged lockdown and restriction of movements. In Kenya, for instance, it resulted in easing some measures on 27th September 2020 in an attempt to reverse the economic strain. By end of October, the effects of these measures were already reversing with a positivity rate of 14 and bed occupancy of 140 percent. The goal of this study was to model the progression of COVID-19 cases in Kenya post reversed curve of the first wave of infections .

Results: An SEIR compartmental model was developed to predict the daily cases of COVID-19 post the reversed curve. The model had 8 compartments containing sub-populatoions of: Susceptible, Exposed, Symptomatic Infectious, Asymptomatic Infectious,Hospitalized,Intesive Care Unit, Deaths and Recovered. The model equations were then solved to obtain the number of cases that would be infected on a daily basis beginning March 14th to January 2021. The model results demonstrated that with the abscence of herd immunity in the general human population, relaxation of the mitigation measures will eventually result to resurgence of COVID-19 cases. The wave of infections length of stay will be 4 months upto January 2021 and will be on the rise to the peak for an estimated 45 days. The cumulative number of cases trend depicts the same pattern as that of the daily cases. It is predicted that the trend will be on the rise till January 2021

Conclusion: Increased vigilance on post reversed COVID-19 curve is indispensable.Continued interventions such as mass and targetted testing, contact tracing and social distancing measures are imperative to ensure that new infections are isolated real time. This will inform new and appropriate interventions amidst the ongoing pandemic.

Background

The novel coronavirus 2019 is a constituent of a group of coronaviruses revealed in 1968 by an eight-member group of virologists.The emergent coronavirus in 2019 was first called '2019-novel coronavirus' (2019-nCov) by the Word Health Organisation (World Health Organization, 2020) on 22th January 2020. Later, WHO christened the disease caused by the virus as 'COVID-19'.The spread of the virus is said to have originated from an animal to human ([1]). Later, through human to human transmission, the disease was spread to most of the countries (220) globally with 57,274,018 confirmed cases and 1,368,000 deaths as at 21st November 2020. The clinical symptoms include; fever, cough, gastro-intestinal infections, difficulty in breathing ([2],[3]). This led to development of global standard precautionary elements for acute respiratory diseases (ARDs) namely; hand hygiene; use of personal protective equipment (PPE) to avoid contact with the patient's body fluids and non-intact skin; respiratory hygiene and cough etiquette; waste management; and cleaning and disinfection of the environment and equipment among other [3]. Since the first case in Kenya was reported on 13th March 2020,various public health interventions which include social distancing measures, wearing of protective masks, curfews, closure of schools, isolation, quarantine and cessation of movement were instituted. On 27th September 2020, the number of cases reported daily were observed to be reducing;positivity rate from 13 to 4 percent in June and september respectively, bed occupancy reduction by 60 percent. This led to relaxation of some of the measures including expansion of age bracket eligible to attend religious gatherings, phased re-opening of learning institutions, withdrawal of cessation of movement restrictions and lifting of travel bans among others. A study done in China by [4] found out that there was a great effect of the interventions implemented in reversing the transmission of new infections. These findings agree with those of ([5] [6] [7]). As Kenya transitions from the first wave of transmission and infections to re-opening of its economy and relaxing many other restrictions, there is a risk of re-emergence of the disease. This could be fueled by casual contacts between individuals, general population behaviour change among others. Disease modeling has been cited as one of the strategic tools in understanding the disease patterns and evaluating the impact of various control measures ([8], [9])

Further to the use of mathematical models to predicting the future of COVID-19 transmission, a study by Thompson referred them to be of utmost importance in determining the undefined impact of "re-opening economies" decisions [9].

An exploration of the Kenyan data revealed that by October 2020, the bed occupancy had gone up to 140 percent, positivity rate had increased to 14 percent, over 15,000 new cases and approximately 300 deaths in a month.The objective of this study to model the progression of COVID-19 cases in Kenya post reversed curve of the previous trend. An SEIR deterministic model was developed taking into consideration the population behavioural change and the relaxed infection prevention interventions even in the absence of known herd protection in the general population. This will be useful in informing planning of resources and creating awareness of the extent to which a second wave may impact the economy.

Main text

Methods

To describe the transmission and spread of COVID-19 , eight(8) disease states compartmental model is used. The total population $N(t)$ at any time t is sub divided into compartments (S) containing the susceptible individuals,(E) the exposed who are presumed to be in the incubation stage of the disease, after exposure some of the individuals will develop the disease without symptoms (A), others will develop the disease and show symptoms (M). The infected will then be hospitalized (H) and its assumed that some will move to critical illness (C). Some of the critically ill will die due to severity of the disease (D). The individuals that recover from either asymptomatic disease, symptomatic disease, hospitalization or critical illnes will be denoted by (R). Where,

$$N(t) = S(t) + E(t) + A(t) + M(t) + H(t) + C(t) + D(t) + R(t) \tag{1}$$

The transmission model is illustrated in the flow diagram labeled Figure 1.

Figure 1 SEIR model of COVID-19 transmission

The COVID-19 transmission model parameters are defined in the table 1.

Table 1 Description of model parameters.

Parameter description	Symbol	Value
Rate of transmission from S to E due to contact with I_A	β_1	0.15
Rate of transmission from S to E due to contact with I_M	β_2	0.08
Proportion of symptomatic infectious people	δ	0.85
Progression rate from E to either I_A or I_S	ω	0.196
Recovery rate of the asymptomatic infected individuals	γ_A	1.0
Recovery rate of the symptomatic infected individuals	γ_M	0.9815
Recovery rate of the hospitalized individuals	γ_H	0.1
Recovery rate of the critically ill individuals	γ_C	0.5
Rate of movement from hospitalization to critical illness condition	ζ	0.3
Hospitalization rate of the symptomatic infected individuals	k	0.044
Death rate of the critically ill due to the virus	λ_c	0.25

The parameters listed in the table above were obtained from literature.

The ordinary differential equations of the transmission model are therefore formulated as follows.

$$\begin{cases} \frac{dS}{dt} = -\frac{\beta_1 SA}{N} - \frac{\beta_2 SM}{N} \\ \frac{dE}{dt} = \left(\frac{\beta_1 A}{N} + \frac{\beta_2 M}{N}\right) S\omega E \\ \frac{dA}{dt} = \delta\omega E - \gamma_A A \\ \frac{dM}{dt} = (1-\delta)\,\omega E\,(\gamma_M M + kM) \\ \frac{dH}{dt} = kM\,(\zeta + \gamma_H)\,H \\ \frac{dC}{dt} = \zeta H - (\gamma_C + \lambda_C)\,C \\ \frac{dD}{dt} = \lambda_C C \\ \frac{dR}{dt} = \gamma_A A + \gamma_M M + \gamma_H H + \gamma_C C \end{cases} \tag{2}$$

where the initial conditions are;

$$S\left(0\right)\geq 0, E\left(0\right)\geq 0, A\left(0\right)\geq 0, M\left(0\right)\geq 0, H\left(0\right)\geq 0 \tag{3}$$

The susceptibles transion to latent phase of the disease at a rate β. Movement from latency to either asymptomatic or symptomatic infected happen at a rate of ω. The infected then progress to hospitalization at a rate k and either move to the critically ill compartment at a rate ζ or to recovery at a rate γ. The critically ill cases could either recover or die at a rate of γ and λ respectively. The recovery rate of the asymptomatic cases is defined by γ. The main aim of social distancing interventions is to minimize the rate at which the infectious individuals come into contact with the susceptible population ([10],[11]). Given that most of the mitigative measures will be relaxed as the daily number of cases report get fewer, the contact rate is likely to go up. This study borrowed closely from the work done by [10] where the contact rate (cr) during disease control interventions and with relaxed restrictions will be denoted by cr_0 and cr_t respectively. Our model assumed that contact rate is progressive and increases with time. Deaths occuring due to critical illness will be denoted by λ.

In this work, the per-capita infectious contact rate, $beta_1$, is allowed to be time dependent through $tanh$ function:

$$\begin{aligned}\beta_1(t) &= \beta_1^* \left(1 + e_1 \cdot \left(-\frac{\tanh(t-\tau_{on})}{\tau_w} + \frac{\tanh(t-\tau_{off})}{\tau_w}\right)\right. \\ &\left. e_2 \cdot \left(\frac{\tanh(t-(\tau_{off}-\tau_{on}))}{\tau_w} - \frac{\tanh(t-\tau_{off})}{\tau_w}\right)\right)\end{aligned} \tag{4}$$

on where $e_1 = 30/100$, $e_2 = 200/100$ and $\tau_w = 2.5$ are constant for adjusting β_1; whereas $\tau_{on} = 90$ days and $\tau_{off} = 240$ days specificy the time period for the two waves. β_1^* per-capita infectious contact rate at time 0. The tan hyperbolic function was used to enable the development of wave 1 and wave 2 peaks.

Results

This section describes the solutions to the ordinary differential equations particulary the daily infections and the estimation of the cumulative number of cases based on the already notified cases in Kenya. Using a deterministic SEIR model, predictions of the daily number of cases are described in Figure 2 from the onset of the pandemic to January 2021. The initial values used are $S(0) = 995, E(0) = 3, I_A(0) = 1, I_M(0) = 1, H(0) = 0, C(0) = 0, D(0) = 0, R(0) = 0$. The second wave of infections was expected to kick off in october 2020 following the re-opening of the economy in September. The resurgence of cases as predicted, would be very steep from the onset unlike the first wave where the curve was a bit slow and gradual at the beginning of the pandemic.The wave of infections length of stay will be 4 months upto January 2021 and will be on the rise to the peak for an estimated 45 days. Figure 3 describes the cumulative number of cases which again depicts the same pattern as that of the daily cases. It is predicted that the trend will be on

the rise till January 2021. The model is a clear indication that with the abscence of herd immunity in the general human population, relaxation of the mitigation measures will eventually result to resurgence of COVID-19 cases. Table 2 describes key indicators of the numbers expeected at the start(onset),maximum daily cases (peak) and the cumulative numbers comparing the actual data and the model. The model predictions are almost 2 times higher than the fitted values in both wave 1 and wave 2. This could be explained by the fact surveillance testing is being done hence there could be exposed population being missed in testing.

Table 2 Summary of select Indicators

Figure 2 Predictions of daily cases of COVID-19

Figure 3 Cumulative cases of COVID-19

Discussion

The model shows that as covid-19 first wave of infections flattens, withdrawal of social restriction measures and reopening of Countries economies is a major risk to resurgence of new infections and at a higher rate of transmission. This could be associated to social behaviour changes, more contact time at places of work, schools, in travels among other avenues.This study results are in agreement with those of ([5] [6]) whose findings were that the aggregate number of cases had an exponential growth with time when mitigative measures were stopped. Other studies like [10] also indicated that re-opening economies and withdrawing interventions could result to devastating state of the disease.Further,[11] found out that ignoring ifection prevention control measures; social distancing, wearing masks, hand washing and travel controls would result to ravaging effects on the susceptible individuals.

With such effects of lifting migitation measures and re-opening of economies, its is important to conduct continous testing for Covid-19 to ensure that new infections are isolated real time to maintain the curve at manageable level and also to inform new policies and regulations amidst the ongoing pandemic. These reserach recommendations were discussed with the national security advisory committee to ensure that proper mitigative measures are still emphasized to control the spread of COVID-19.

Limitations

Some global COVID-19 modelling parameters were adopted for use in this work.

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Author's contributions
J.K. wrote the main manuscript text and prepared all the figures and the tables. S.M. and R.M. provided mentorship, reviewed the manuscript and proof read the final text.

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Availability of data and materials
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Not Applicable.

Consent for publish
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Competing interests
The authors declare that they have no competing interests.

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Figures

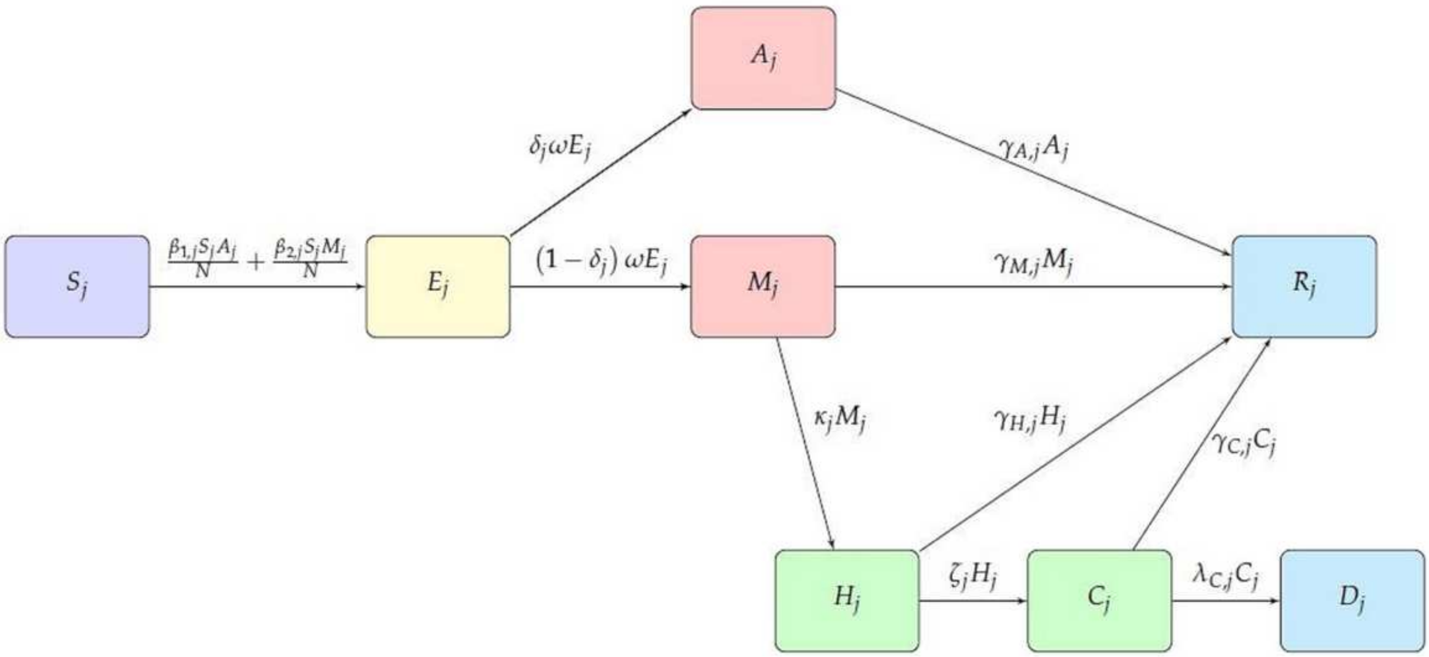

Figure 1

SEIR modelofCOVID-19transmission

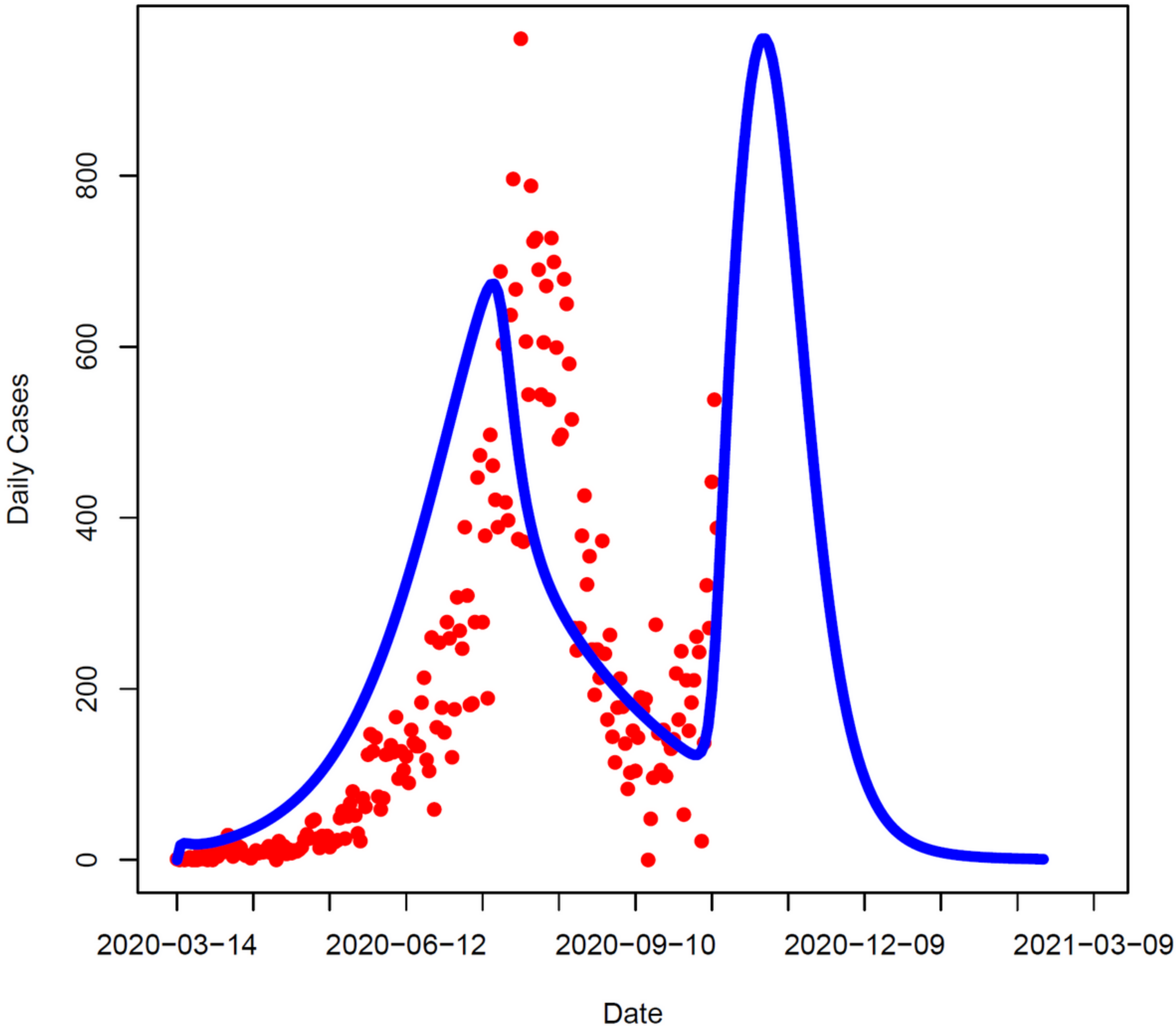

Figure 2

Predictions ofdailycasesofCOVID-19

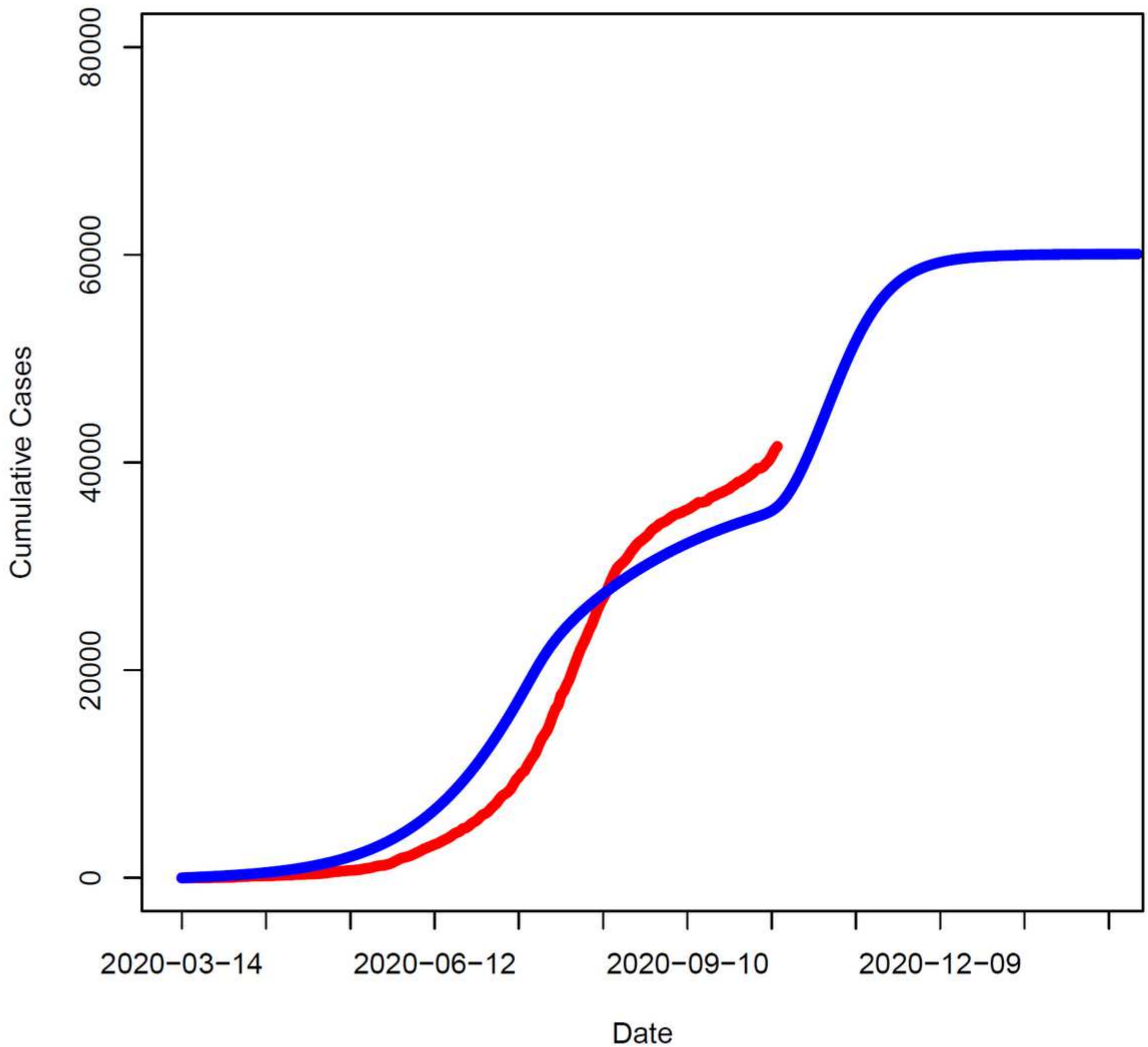

Figure 3

Cumulative casesofCOVID-19

Supplementary Files

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

- Table1.jpg
- Table2.png