Original Article

Validation of COVID-19 Spread Model by Early Cases from Spain

Isack E. Kibona, Jeremiah J. Ruhere, Violet G. Saria
Department of Mathematics and Statistics, Mbeya University of Science and Technology, Mbeya, Tanzania

Abstract

This article intends to illustrate the coronavirus disease 2019 (COVID-19) model if strict restriction is not enforced. Early COVID-19 cases from Spain have been considered an example. Thus, this article is for the estimation of specific parameter particularly to one of the most hit countries in April 2020. Our essence is the possibility to spot a natural model of COVID-19. The cases between March 1 and 15, 2020 have been taken to validate and estimate the parameter of the model. Parameters were estimated by a nlinfit function from MATLAB developed by Levenberg–Marquardt, and thus, so is the reproduction number (R_0). R_0 was found greater than the unit, which is catastrophic. Cases of COVID-19 between March 1 and 15 have been chosen to validate the model because in this earlier stage of the pandemic, Spain restrictions against the spread were assumed not enough to impede the pace of natural spread to the pandemic. Had it not been the lockdown that followed after the mentioned dates, by April 15, 2020, Spain would have been in a more catastrophic situation by >3,400,000 COVID-19 infection cases far worse from 180,695 cases that happened.

Keywords: Coronavirus disease 2019, infection cases, pandemic Spain restrictions

INTRODUCTION

The word corona originates from a Latin word which means a crown. Most scientists and researchers concede that the virus was named so because the virus had phenotype figure that looks like a king's crown when observed under microscope.[1] Max *et al*.[2] explained that there are so many kinds of coronavirus that cause about 30% of common colds around the world. This latest coronavirus causing disease to human was initially named as the 2019-novel coronavirus on January 12, 2020 by the World Health Organization (WHO). The WHO officially named the disease as coronavirus disease 2019 (COVID-19) and the Coronavirus Study Group of the International Committee proposed to name the new coronavirus as severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2), both issued on February 11, 2020.[3]

COVID-19 outbreak was once noted in Wuhan, Hubei Province, China, on December 31, 2019. Tian-Mu Chen *et al*.[4] suggested that this SARS-CoV-2 might have been originated from bats and transmitted to humans by eating seafood market products (hosts) of the virus. At the time of writing this article, coronavirus infecting people has now been manifested all over the continents within >212 territories. The World Health Systems spend most of the resources into learning about treating and preventing COVID-19 infections in all countries by enforcing mass conference cancellations, travel restrictions, social distancing, and other unscientific prevention measures like prayers.[5]

This article intends to formulate and justify a mathematical model that represents the natural spread of COVID-19 using Spain data. Visconti, Eduardo Enrique Tal, justified that there was a natural spread of coronavirus infections among people in Spain from the first onset of the infections that was confirmed on January 31, 2020.[6] In Spain, COVID-19 was discovered when a German tourist was confirmed to be positive of COVID-19 in La Gomera, Canary Islands. Until March 13, 2020, COVID-19 cases were confirmed in almost 50 provinces

Access this article online
Quick Response Code:
Website:
www.matrixscipharma.org
DOI:
10.4103/MTSP.MTSP_12_20

Address for correspondence: Prof. Isack E. Kibona,
Department of Mathematics and Statistics, Mbeya University of Science and Technology, P. O. Box: 131, Mbeya 00255, Tanzania.
E-mail: ikibona@mustnet.ac.tz

How to cite this article: Kibona IE, Ruhere JJ, Saria VG. Validation of COVID-19 spread model by early cases from Spain. Matrix Sci Pharma 2020;4:60-4.

Received: 21-Sep-2020 **Accepted:** 24-Sep-2020 **Available Online:** 30-Nov-2020

of Spain, followed by a state of alarm and national lockdown that was imposed exactly on March 14, 2020. This study is about the verification of the COVID-19 deterministic model by early infection cases of COVID-19. In so doing parameters of the model particularly for Spain are going to be estimated. Presumably, Spain COVID-19 cases that range from March 1 to 15, 2020 were spreading naturally.

MODEL DEVELOPMENT

A population of size N at time, t with constant inflow of susceptible at a rate of Λ is considered. The population is divided into five compartments. There is susceptible compartment (S), refers to individuals not infected, but is liable to infections. Exposed compartment (E), infectious class (I), and recovery compartment (R) are individuals who have recovered from COVID-19, and we have included compartment of death (D) which is a collection of individuals dying due to induced death by COVID-19. It is as well been assumed that individuals recovering from COVID-19 are not reinfected.

β is an infection rate resulting from interaction of S with infected individuals, I or by contaminated environment. μ is the natural death rate. Table 1 is a summary of parameters and their definitions. The model can be expressed in a flow diagram as in Figure 1. Therefore, the system of equations 1 is a proposed model of COVID-19 in a no or ignorable lockdown against the spread of the epidemic population.

$$\begin{cases} S'(t) = A - \beta S\dfrac{I}{N} - \mu S; \\ E'(t) = \beta S\dfrac{I}{N} - (\sigma + \mu)E; \\ I'(t) = \sigma E - (\gamma + \delta + \mu)I; \\ R'(t) = \gamma I - \mu R. \\ D'(t) = \delta I. \end{cases} \tag{1}$$

BASIC REPRODUCTION NUMBER AND EQUILIBRIUM OF THE MODEL

In order to analytically understand the spread of pandemic, basic reproduction number (R_0) is the most vital quantity in epidemiology. R_0 is basically the average number of new infectious cases caused by a single infected individual in a totally susceptible population. R_0 from equation 1 has been estimated by the next-generation method. Thus

$$R_0 = \frac{\sigma\beta}{(\gamma + \delta + \mu)(\sigma + \mu)} \tag{2}$$

Table 1: The summarized definition of parameters

Parameter	Definition
Λ	Recruitment rate
β	Infection rate
μ	Natural mortality rate
σ	Induced death rate by COVID-19
γ	Recovery rate from disease I

COVID-19: Coronavirus disease 19

The disease-free equilibrium point (DFE), Q^0 is simply evaluated from the system of equations 1, by substituting $E^0 = I^0 = R^0 = 0$ and $St = Et = It = Rt = 0$, then solve for Q^0. Thus, the DFE point exists as follows:

$$Q^0\left(S^0 = \frac{A}{\propto}, E^0 = 0, I^0 = 0, R^0 = 0\right) \tag{3}$$

The endemic equilibrium point, $Q^*(S = S^*, E = E^*, I = I^*, R = R^*)$ is obtained by solving for I^* $f = 0$ at the equilibrium point of the system 1. Thus $Q^*(S^*, E^*, I^*, R^*)$ has been found, where:

$$Q^*(S^* = \frac{A\beta}{R_0(\beta - \delta)(\mu + \sigma)} + \frac{(\mu + \gamma)A}{(\beta - \delta)\mu}, E^* = \frac{A\mu + \delta + \gamma}{\beta - '}(R_0 - 1), I^* = \frac{A}{(\beta - \delta)}(R_0 - 1), R^* = \frac{A\gamma}{\mu(\beta - \tilde{A})}(R_0 - 1), \tag{4}$$

from which it can be proved that the endemic equilibrium exists if $R_0 > 1$.

SIMULATION OF THE MODEL

The COVID-19 infection cases for Spain have carefully been observed and recorded from March 1 to 15, 2020 as listed in Table 2.[7] Between March 1 and 15, 2020, COVID-19 cases in Spain demonstrate a typical COVID-19 deterministic model.

In order to simulate a situation in Spain, the information in Table 2 with a corresponding curve of COVID-19 infection cases Figure 2a. Were employed with the aid of the Levenberg–Marquardt algorithm for parameter estimation. The parameters were estimated as listed in Table 3.

Simulations have depicted that for $R_0 > 1$ leads to the existence of the epidemic for longer time than when $R_0 < 1$, this is true if recovered individuals are not reinfected, Figure 3b.

Otherwise, with $R_0 < 1$, the spread of the epidemic immediately slows and goes to extinction, Figure 4b.

Impact of lockdown to the spread of COVID-19 in Spain

The estimation of R_0 for Spain between March 1 and 15, 2020 has been found to be greater than the unit according to estimated parameters of Table 3.

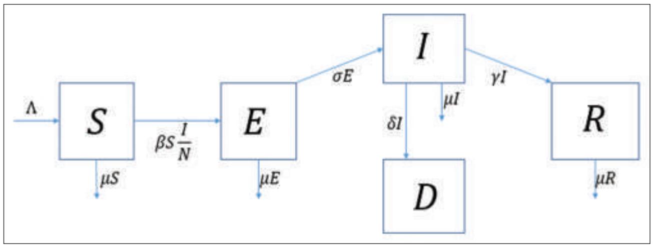


Figure 1: Model flow diagram

Table 2: Number of coronavirus disease 19 cases in Spain from March 1 to 15, 2020

March 2020	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Number of cases (*I*)	84	120	165	228	282	401	525	674	1231	1695	2277	3146	5232	6391	7988
Recovered (*R*)	0	0	0	0	1	4	28	30	30	133	181	187	191	515	515
Number of deaths (*D*)	0	0	1	2	5	8	10	17	30	36	55	86	133	196	294

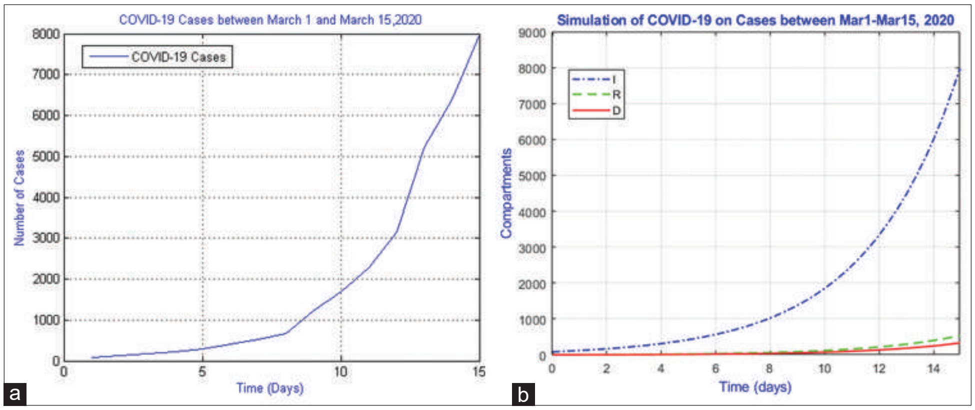


Figure 2: (a and b) Plots of coronavirus disease 2019 cases both original and simulated cases

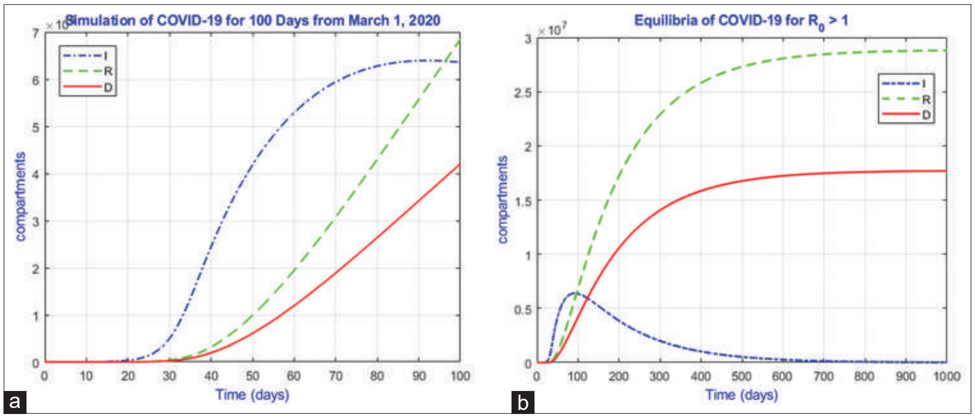


Figure 3: (a and b) Simulations of coronavirus disease 2019 cases for $R0 > 1$

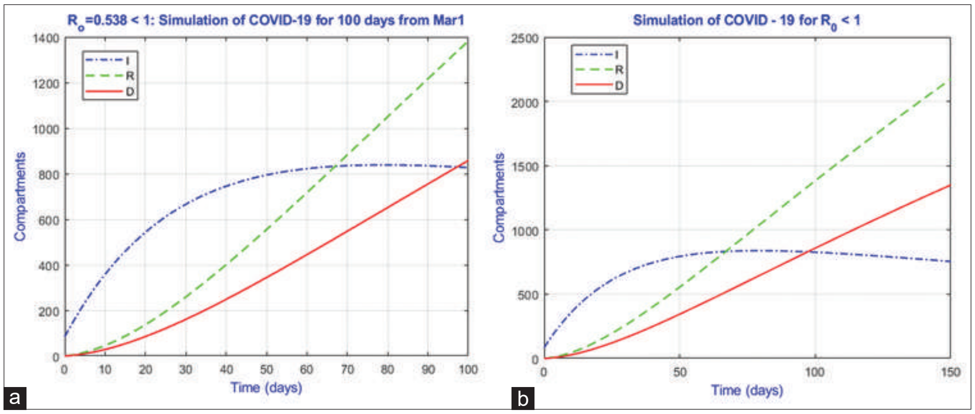


Figure 4: (a and b) Simulations of coronavirus disease 2019 cases for $R0 < 1$

Had it been no lockdown after this period, then Spain would have suffered a more catastrophic state than what happened, Figure 5a and b.

That is the impact of lockdown as it was insisted by the government particularly after this period, the number of COVID-19 infection cases accumulated to 180,695, which

Table 3: Estimated parameters of the proposed coronavirus disease 19 model

Parameter	Value	Units	Source
Λ	1057	Births per day	[7]
β	14.0273	Per day per individual	nlinfit
μ	0.00002524	Natural deaths per day per individual	[7]
σ	0.0067	Per day per individual	nlinfit
γ	0.0200	Per day per individual	nlinfit
δ	0.0124	Per day per individual	nlinfit

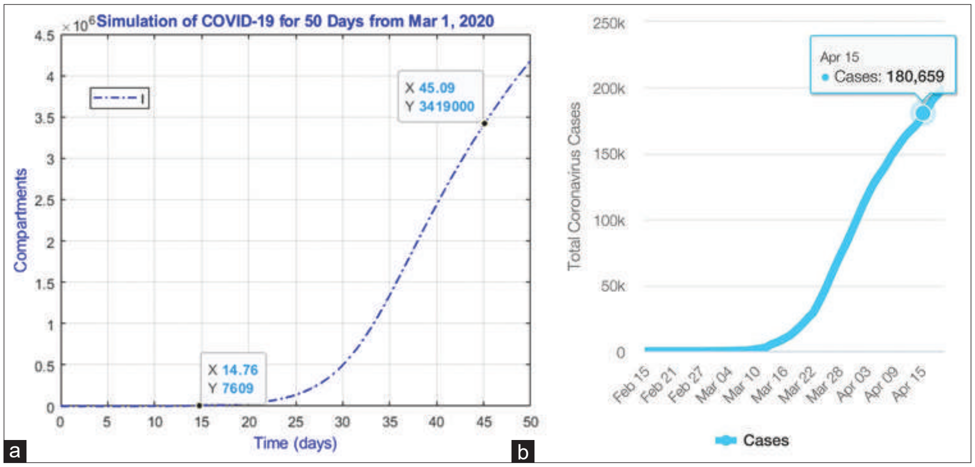


Figure 5: (a and b) Coronavirus disease 2019 infection cases as of April 15, 2020

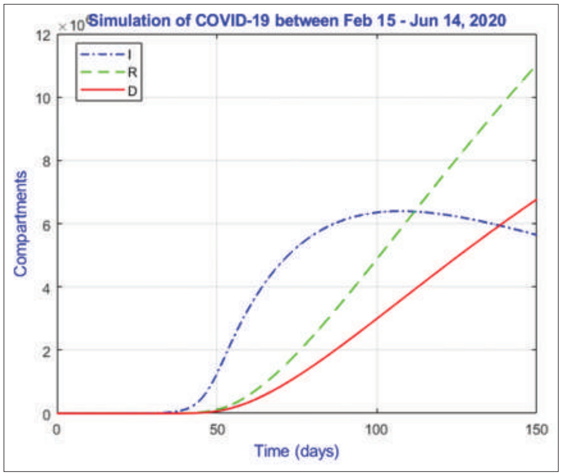


Figure 6: Projection of coronavirus disease 2019 infection cases by June 14, 2020

is far lower than 3,419,000, Figure 5a from simulation. Therefore, lockdown saved 3,238,305 possible infection cases from COVID-19. Moreover, extending the projection to June 14, 2020, Spain shall have reached its peak, and therefore, the number of infections in 24 h will keep lowering, Figure 6.

DISCUSSION AND CONCLUSION

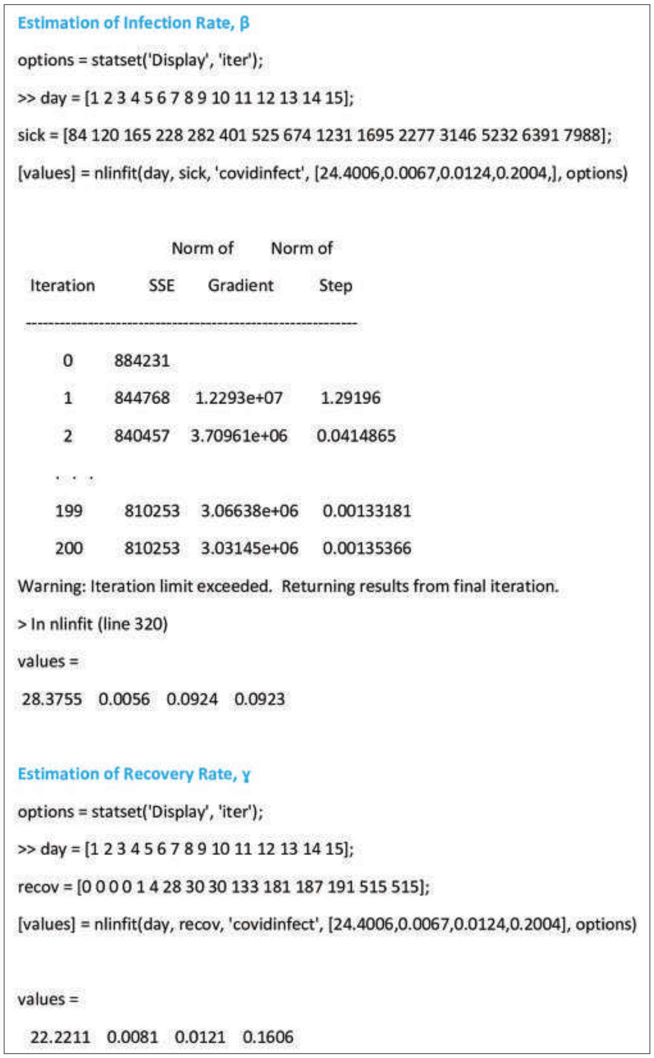
COVID-19 is a pandemic like other infectious diseases; it can be modeled, simulated, and can be controlled. One of the immediate control methods is the hygienic approach including lockdown. Lockdown suggests minimization of contact presumably between infected individuals and susceptible group, as well with contaminated environment. Basing on the consequences to economy one side of COVID-19 fighters is suggesting a highly restricted hygienic environment would suffice to combat COVID-19 instead of lockdown. The hygienic approach only is far more advantages compared to lockdown because people continue with not only economic activities but also social, and so on.

Future researches

The study of COVID-19 in this context has not analytical been fully analyzed including and not limited to equilibrium stability. Moreover, the study has not included intervention by lockdown, or what if vaccination is invented. Not only that but also, we think that a model could be more appealing by explicitly analyzing how contaminated environment by the COVID-19 virus directly impact the spread of COVID-19. Good parameter estimation other than the nlinfit algorithm may help to determine the possible number of deaths a community or the world is likely to face. Basing on all these, more insight for future research is open for further refinement of the study.

Acknowledgments

The Mbeya University of Science and Technology is vigilant and dynamic striving to expand both in the number



Estimation of Infection Rate, β

```
options = statset('Display', 'iter');
>> day = [1 2 3 4 5 6 7 8 9 10 11 12 13 14 15];
sick = [84 120 165 228 282 401 525 674 1231 1695 2277 3146 5232 6391 7988];
[values] = nlinfit(day, sick, 'covidinfect', [24.4006,0.0067,0.0124,0.2004,], options)


                        Norm of       Norm of
 Iteration        SSE      Gradient        Step
 -----------------------------------------------------------

     0      884231
     1      844768    1.2293e+07      1.29196
     2      840457   3.70961e+06     0.0414865
     . . .
    199      810253   3.06638e+06    0.00133181
    200      810253   3.03145e+06    0.00135366
Warning: Iteration limit exceeded.  Returning results from final iteration.
> In nlinfit (line 320)
values =
 28.3755   0.0056   0.0924   0.0923
```

Estimation of Recovery Rate, γ

```
options = statset('Display', 'iter');
>> day = [1 2 3 4 5 6 7 8 9 10 11 12 13 14 15];
recov = [0 0 0 0 1 4 28 30 30 133 181 187 191 515 515];
[values] = nlinfit(day, recov, 'covidinfect', [24.4006,0.0067,0.0124,0.2004], options)


values =
  22.2211   0.0081   0.0121   0.1606
```

Figure 7: Nlinfit algorithm sample for Estimation of the Model Parameter

of students and curricula in science and technology. The university is also a front liner promoting excellence not only in teaching and consultancy but has also put emphasize on research activities. Through the Department of Mathematics and Statistics, academic staff are sorting out to research as healthy as mathematicians. Mathematical modeling of COVID-19 is one of an emergent concern to be addressed in this department. The university is financing all necessities to enhance researches be able to address the COVID-19 pandemic.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Alexander OF, Ludmila VC, Andrew VG. A new pelobiont protist pelomyxa corona sp. n. (peloflagellatea, pelobiontida). Protistology 2004;3:233-41.
2. Max R, Hannah R, Esteban OO, Joe H. Coronavirus Disease (COVID-19), Our World in data; 2020.
3. Yan-Rong G, Qing-Dong C, Zhong-Si H, Yuan-Yang T, Shou-Deng C, Hong-Jun J, *et al*. The origin, transmission and clinical therapies on coronavirus disease 2019 (COVID-19) outbreak–an update on the status. Mil Med Res 2020;1:1-10.
4. Tian-Mu C, Jia R, Qiu-Peng W, Ze-Yu Z, Jing-An C, Ling Y, A mathematical model for simulating the phase-based transmissibility of a novel coronavirus. Infect Dis Poverty 2020;1:1-8.
5. John W. Preventing a covid-19 Pandemic; 2020.
6. Eduardo ETV, Guía de prevención de riesgos laborales en el ámbito de la empresa ante la crisis sanitaria del covid-19., Gestión práctica de riesgos laborales: Integración y desarrollo de la gestión de la prevención. 2020;180:10-21.
7. Worldometers; 2020. Available from: https://www.worldometers.info/coronavirus/country/spain/. [Last accessed on 25 Aug 2020].