



Quarantine vs Social Consciousness: A Prediction to Control COVID-19 Infection

Md. Shahriar Mahmud¹, Md. Kamrujjaman^{1*}, J. Jubyrea²,
Md. Shahidul Islam¹ and Md. Shafiqul Islam³

¹Department of Mathematics, University of Dhaka, Dhaka 1000, Bangladesh.

²Department of Computer Science and Engineering, International Islamic University Chittagong, Bangladesh.

³School of Mathematical and Computational Sciences, University of Prince Edward Island, Charlottetown, PE, Canada.

Authors' contributions

This work was carried out in collaboration among all authors. Authors MSM and MK derived the mathematical model, designed the study and the first draft of the manuscript. Authors MSM, MK and JJ carried out the data analysis, some numerical simulations and the parameter estimations. Authors JJ, Md. Shahidul Islam and Md. Shafiqul Islam provided the literature review and final drafting. All authors contributed to the reviewing of the manuscript. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/JALSI/2020/v23i330150

Editor(s):

(1) Dr. Martin Koller, University of Graz, Austria.

Reviewers:

(1) Longkun Tang, Huaqiao University, China.

(2) A. George Maria Selvam, Sacred Heart College (Autonomous), India.

Complete Peer review History: <http://www.sdiarticle4.com/review-history/56918>

Received: 24 April 2020

Accepted: 15 May 2020

Published: 20 May 2020

Original Research Article

ABSTRACT

Background: The world is now in an emergency of preventing the drastic spread of COVID-19. After the infection was first reported in December 2019, almost every country did not pay attention to this highly contaminated disease and failed to react swiftly. Now the whole planet is in a vulnerable state, resulting to increase the mortality rate and facing difficulties in all socio-economic aspects. That is why we have the urge to develop an efficient mathematical model (quarantine) based on social consciousness to control the epidemic.

*Corresponding author: E-mail: kamrujjaman@du.ac.bd;

Methods: This is a quarantine mathematical model. The outcome of the system is dependent on social consciousness. We have calculated the awareness level by considering various socio-economic factor of each country. In our model, the parameters are Education Index, Gross Domestic Product (GDP) per capita, population density, high literacy and stable economy. To maximize the efficiency of the model, it has to be implemented in initial stage. However, strict application of the method in vigorous stage of epidemic will also bring a satisfactory outcome.

Results: In Spain, quarantine was effected on March 14, 2020. Spain experienced an increase in reported cases for 13 days of quarantine enforcement and from the 14th day, daily reported cases started to decrease with small fluctuation. Government ensured the social isolation through quarantine. After imposition of a quarantine on March 9, 2020 in Italy, within 13 days of lock-down, the maximum number of infection started to decrease. Similar results observed in France. Higher social consciousness would decrease the number of infected population dramatically while minimal or lower awareness will do a outburst.

Conclusion: Outbreak will be in control of health care system which yields to reduce the death rate and will ensure social and economic stability.

Keywords: Coronavirus; COVID-19; consciousness; data analysis; mathematical model; control.

2010 Mathematics Subject Classification: 53G25, 83C05, 57N16.

1 INTRODUCTION

The coronavirus disease pandemic caused by SARS-CoV-2 is having a devastating impact across the world. Almost all countries and territories (212 countries and territories around the world) are victim with total 4,063,147 reported cases globally on May 09, 2020 and this is a global health emergency [1, 2]. The virus is related to the coronavirus responsible for the SARS outbreak of 2003 named SARS-CoV-1, and the virus is zoonotic [3]. In March 13, 2020, the World Health Organization (WHO) considered Europe as hot spot of the 201920 coronavirus pandemic, and by May 09 (2020), 48 countries and territories of Europe are affected by the outbreak [1, 2, 4]. The daily reported cases are being doubled over periods of 2 to 4 days by country across Europe [5], and the phenomenon has drawn a lot of attention.

In this paper, we have studied three European countries Spain, Italy and France; all these countries have higher socio-economic index [4, 6, 7]. So generally we can say people of these habitat are well aware of any given situation. In COVID-19 pandemic, they are apparently unprepared or may not have paid attention well.

This literature offers an ordinary differential equation (ODE) model to drag down the spread

of COVID-19, with the influence of social consciousness towards the epidemic. Our prescribed model also determines the ongoing social response, this model also predicts the scenario of COVID-19 when handled with a higher social consciousness level. In the following manner, we have discovered the main novelty of our work:

- The model is designed for different types of contaminated diseases (for example, SARS-CoV-1, Ebola, MERS, Flu etc.) when it is required to handle without proper medication.
- This determines the consciousness level for any given time and the percentage of social awareness required to gain the best control against the outbreak.
- The outcome of this model is applicable at any stage of epidemic with distinct outcome.
- If the solution is applied in the initial stage of contamination, the disease will be in control of the health care system and will not affect socio-economic context.
- We would be able to handle any future viral outbreak without or with less loss of lives or damaging the economy, and will be able to buy us some more time to investigate medication.

The paper is designed as follows. Materials and methods are elaborately discussed in Section 2. Data management, model and its solution are described in three subsections of Section 2. Section 3.1 is accomplished results and discussions of data analysis in three subsections: Cases in Spain (Subsection 3.2), Cases in Italy (Subsection 3.3) and Cases in France (Subsection 3.4). Finally, Section 4 outlines the summary and discussion of the results.

2 MATERIALS AND METHODS

2.1 Data Management

In this study, we consider three countries Spain, Italy and France infected by SARS-CoV-2 virus and collected available online data in chronological order from Worldometer [1, 2]. We consider these three countries since in the end of march all these territories were the most affected countries in COVID-19 out of many. We take the data up to 06 April, 2020 from the first day of infection to present the results graphically.

We summarize the officially reported data from Worldometers in Figs. 1 to 9. There is an increasing-decreasing-increasing trend of daily new confirmed cases. Cumulative cases are presented there which is either increasing or flatten. To ensure the curve fitting, we do not include any additional data after April 06, 2020. For simplicity and to compare the results between data analysis and model solutions, we notice that 0 presents the first day of all countries; Spain, Italy and France.

In the following section, we will discuss our proposed mathematical model elaborately.

2.2 Mathematical Model

In the literature, various types of mathematical models are developed to prevent or cure diseases. In the case of Mathematical models for infectious diseases, the classical SIS, SIR, and SEIR models are examples of mathematical models for the determination of critical conditions of disease development asymptotically in any population [8, 9, 10, 11]. Since there is no proper medication or vaccine for the disease COVID-19, prevention is the only and main methodology

for getting protected from COVID-19. Let $I(t)$ be the number of infected individuals at time t in unit of day and $Q'(t)$ is the increasing rate of change of social consciousness $Q(t)$ such as quarantine, hand washing, social distancing *etc.* due to COVID-19 pandemic situation caused by coronavirus in recent times. We propose the following ODE model based on quarantine and social consciousness:

$$Q' = \gamma Q - \alpha Q^2, \quad (2.1)$$

$$I' = rI \left(1 - \frac{I}{K}\right) - \beta Q, \quad (2.2)$$

for $t \in (0, \infty)$ with initial conditions

$$Q(0) = a, \quad I(0) = I_0, \quad (2.3)$$

where, the social consciousness level $\gamma \propto (eg)/d$, and e, g, d are the Education Index, GDP per capita and Population density of the considering country respectively where it is assumed that a stable economy and high rate of literacy may help people to be more responsible to the society. Note that $\gamma = \sigma \frac{eg}{d}$, where σ is a constant which represents the mass social responsibility index of a certain country which may vary from nation to nation. The parameter α is very small with respect to $\gamma \equiv (eg)/d$ (i.e. $\gamma \gg \alpha$) making an correction over the exponential growth of $Q(t)$. The parameter r is the intrinsic growth rate, K is the carrying capacity and β is the rate of influence of social consciousness to pull down the propagation scene. In the Mathematical model (2.2), the Logistic growth function is considered to make the infection bounded [12].

The above mathematical model shows the importance of social consciousness to control such a contagious infection of COVID-19. This model evaluates the current consciousness level in a society to fight back the attack of COVID-19 and also measures the effective consciousness level that could pull down the outbreak at the primary stage if it could be imposed in time at the perfect level.

2.3 Solution of the Model

We are concern about the control of the infection growth presented in the second equation (2.2)

of the model. To determine the change in $I(t)$ we first evaluate the solution of the first equation (2.1) and then place the solution of $Q(t)$ in the second equation (2.2).

From the first equation (2.1) of the system we get

$$\begin{aligned} \frac{dQ(t)}{dt} &= \gamma Q(t) - \alpha Q^2(t) \\ \Rightarrow \frac{dQ(t)}{\gamma Q(t) - \alpha Q^2(t)} &= dt \end{aligned}$$

Now, integrating the equation on both sides, we have

$$\begin{aligned} \int_{Q(0)}^{Q(t)} \frac{1}{\gamma Q(t) - \alpha Q^2(t)} dQ(t) &= \int_{t_0}^t dt \\ \Rightarrow \int_a^{Q(t)} \frac{-\frac{\gamma}{Q^2(t)}}{\frac{\gamma}{Q(t)} - \alpha} dQ(t) &= -\gamma \int_0^t dt \end{aligned}$$

which yields

$$Q(t) = \frac{\gamma}{\left(\frac{\gamma}{a} - \alpha\right) e^{-\gamma t} + \alpha} \quad (2.4)$$

Now, the second equation (2.2) gives

$$\frac{dI(t)}{dt} = rI(t) \left(1 - \frac{I(t)}{K}\right) - \beta Q(t)$$

After few steps of mathematical simplification, we obtain

$$\frac{dI(t)}{(I(t) - K)^2 + K \left(\frac{\beta}{r} Q(t) - K\right)} = -\frac{r}{K} dt$$

Integrating within the reasoning limits gives

$$\int_{I_0}^{I(t)} \frac{dI(t)}{(I(t) - K)^2 + K \left(\frac{\beta}{r} Q(t) - K\right)} = -\frac{rt}{K} \quad (2.5)$$

The solution of integral equation (2.5) is not straightforward since the denominator contains $Q(t)$ which depends on time (see (2.4) for details). Hence we solve (2.5) numerically to find $I(t)$. As $I(t)$ being the number of infected individuals, $I(t) \geq 0$.

3 RESULTS AND DISCUSSION

3.1 Numerical Validation

During last week of March and first week of April, 2020, the countries Spain, Italy and France were in the list of top positions of confirmed coronavirus (COVID-19) cases. In this manuscript, we have used COVID-19 data in Wordometer [1] for Spain, Italy and France up to 06 April, 2020 from and studied the model control prediction for these countries using the Runge-Kutta fourth order method.

3.2 Cases in Spain

The following figure (see Fig. 1) shows that the current COVID-19 situation in Spain matches the model data at the average social consciousness level 49%.

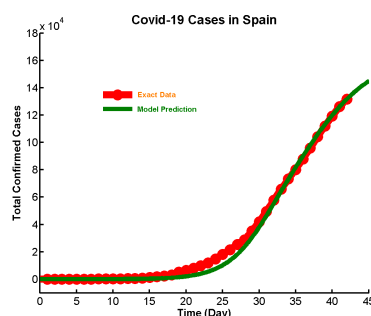


Fig. 1. Model data coincides exact data at 49% social consciousness level

From resources published by European Union and other sources [4, 6, 7] for Spain, we consider the parameter values as

$$e = 0.9825, \quad g = 29.586 \text{ (thousand USD),}$$

$$\text{and } d = 91.4 \text{ (per square km),}$$

which shows the 49% social consciousness. Note that

$$\gamma = \sigma \frac{0.9825 \times 29.586}{91.4},$$

$$\Rightarrow \sigma = 1.5407, \text{ where } \gamma = 49\%.$$

It is remarked that during this study, first we fit the existing discrete data with model solution to find the conscious level γ as shown in Fig. 1.

If σ changes then the value of γ also changes. In Figs. 2-3 for Spain and similarly for other two countries, we have established the results which shows the optimal control policy to reduce the infection is estimated by the correlation between σ and γ .

The Fig. 3 indicates that if the people of Spain are able to continue holding this social awareness level, there will be no new infection after the 69-th day of the first confirmed case of COVID-19.

The model is also shows in Fig. 2 what could happen without social consciousness and with rapid implementation of social consciousness before community transmission or initial stage (phase 2) of infection propagation.

3.3 Cases in Italy

Fig. 4 resembles the COVID-19 situation in Italy that coincides with the model data at the level of 57.6% social consciousness in average.

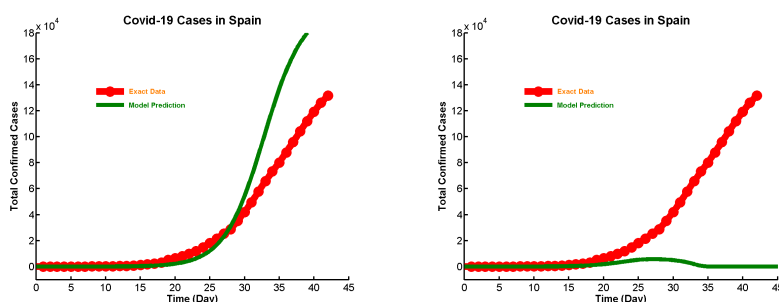


Fig. 2. Model simulation at 0% and 65% social consciousness level respectively

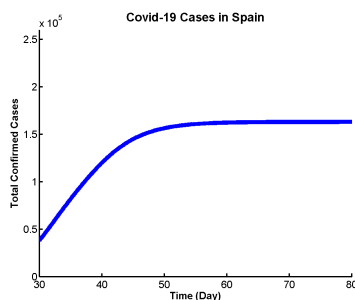


Fig. 3. Model solution (data) predicts the control of COVID-19 in Spain

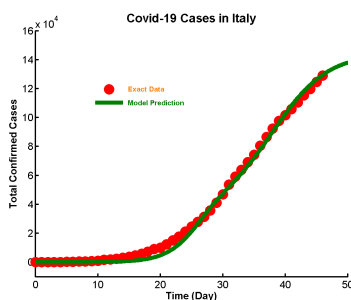


Fig. 4. Model data coincides exact data at 57.6% social consciousness level

For Italy, we get from $\gamma = \sigma \frac{eg}{d}$:

$$e = 0.9885, \quad g = 33.156 \text{ (thousand USD),}$$

$$\text{and } d = 205.45 \text{ (per square km).}$$

So, the mass social responsibility index equates to

$$\gamma = \sigma \frac{0.9885 \times 33.156}{205.45},$$

$$\Rightarrow \sigma = 3.6107, \quad \text{where } \gamma = 57.6\%.$$

So, the mass social responsibility index equates to 3.6107.

The Fig. 5 shows what could happen without social consciousness and with rapid implementation of social consciousness at before community transmission or initial stage (phase 2) of infection propagation.

This Fig. 6 resembles that the current social awareness level can make the pandemic to infect no new case in Italy after the 57-th day, since the first suspected individual tested COVID-19 positive.

3.4 Cases in France

The current COVID-19 situation in France with the model data at the average social consciousness level 47.5% and mass social responsibility index 1.3935 is presented in Fig. 7. Accordingly the mass social responsibility index of France is calculated and we obtain

$$\sigma = \frac{47.5 \times 117.37}{0.99 \times 40.411} = 1.3935.$$

The impact of no social consciousness and rapid implementation of social consciousness level before community transmission or initial stage (phase 2) of infection propagation is shown in Fig. 8.

Fig. 9 presents the scenario that after the 71-st day of facing COVID-19 outbreak, no new cases will be found if the French people can continue their present social consciousness level.

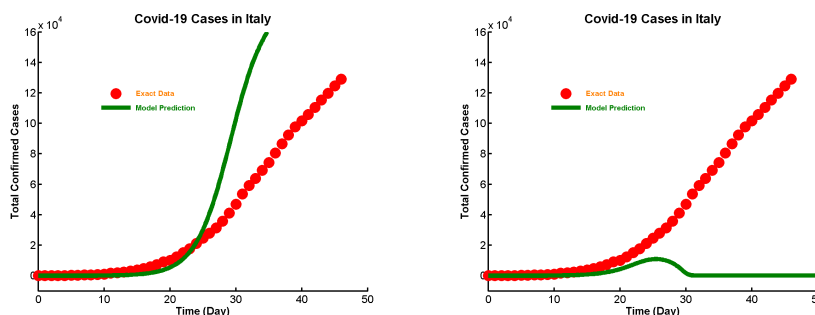


Fig. 5. Model simulation at 0% and 66% social consciousness level respectively

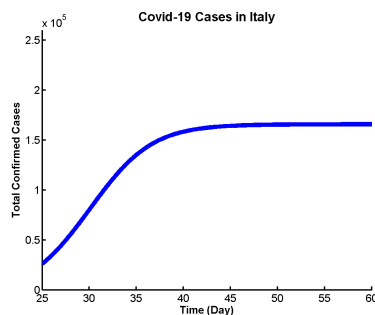


Fig. 6. Model solution (data) predicts the control of COVID-19 in Italy

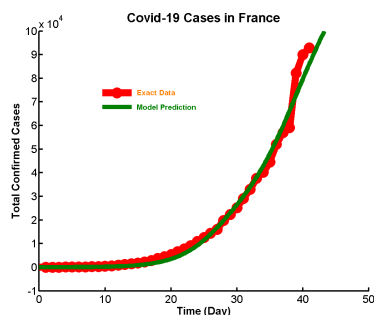


Fig. 7. Model data coincides exact data at 47.5% social consciousness level

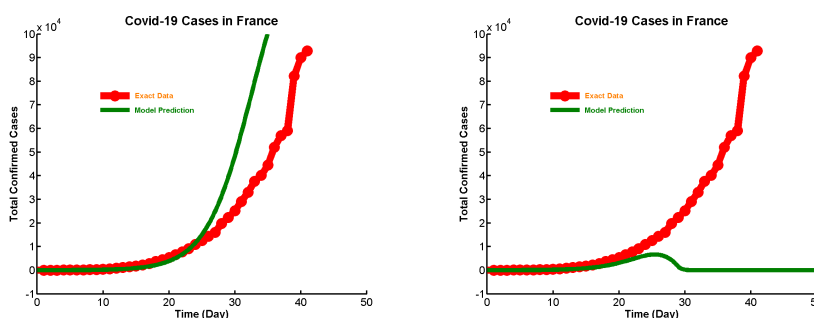


Fig. 8. Model simulation at 0% and 52% social consciousness level respectively

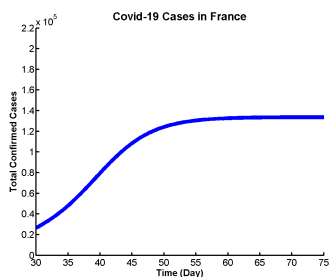


Fig. 9. Model solution (data) predicts the control of COVID-19 in France

4 CONCLUSION

Mathematical and computational models can help to understand biological scenarios and can predict epidemiological aspects. In this paper, we proposed a model to interpret the importance of social consciousness. The proposed mathematical model validates the ongoing viral cluster of Spain, Italy and France, and shows the current consciousness level in these countries. It also describes the possible outcome of the

pandemic, when social consciousness raised 16% (Spain), 9% (Italy) and 5% (France) more for the respected countries. It can be said that on average only 10% increased social consciousness could possess a significant impact on disease control for any given country. The manuscript also describe the effectual outcome of disease propagation when social consciousness improved on any n^{th} day (at any stage of outbreak).

We hope that our modelling of social consciousness will assist in greater aspects. These findings will motivate the mankind to understand the importance of rapid social consciousness action. Rapid social awareness can help us to fight back this type of highly cognitive disease in the current time or in near future. This way the scientist will be able have some time in inventing medication.

ACKNOWLEDGEMENTS

The authors acknowledged to the anonymous reviewers for their constructive suggestions to the early version of the manuscript. The author M. Kamrujjaman research was partially supported by TWAS grant: 2019.19 – 169 RG/MATHS/AS.I.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

REFERENCES

- [1] worldometer, COVID-19 Coronavirus/cases; 2020. Available: <https://www.worldometers.info/coronavirus/coronavirus-cases/#recovered>
- [2] World Health Organization (WHO); 2020. Available: <https://www.who.int/health-topics/coronavirus>
- [3] Ahmad T, Khan M, et al. COVID-19: Zoonotic aspects. Travel Medicine and Infectious Disease, Elsevier; 2020.
- [4] European Union (EU). Available: https://europa.eu/european-union/index_en
- [5] Coronavirus Disease (COVID-19) Research and statistics. Archived; 2020. Available: <https://www.ourworldindata.org/coronavirus>
- [6] European Central Bank (ECB). Available: <https://www.ecb.europa.eu/home/html/index.en.html>
- [7] Michalos, Alex C. (Ed.) Encyclopedia of quality of life and well-being research. Springer. 2014;1816-1819.
- [8] Murray J. Mathematical Biology I, third edition, Springer-Verlag, Heidelberg; 2002.
- [9] Kamrujjaman M, Mahmud MS, Islam S. Coronavirus outbreak and the mathematical growth map of Covid-19. Annual Research & Review in Biology. 2020;35(1): 72-78.
- [10] Volpert V, Banerjee M, Petrovskii S. On a quarantine model of coronavirus infection and data analysis. Mathematical Modelling of Natural Phenomena. 2020;15(24):1-6.
- [11] Lin Q, Zhao S, Gao D, He D. A conceptual model for the coronavirus disease 2019 (COVID-19) outbreak in Wuhan, China with individual reaction and governmental action. International Journal of Infectious Diseases. 2020;63:211-216.
- [12] Verhulst PF. Notice sur la loi que la population suit dans son accroissement. Corr. Math. Physics. 1838;10:113.

© 2020 Mahmud et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution and reproduction in any medium, provided the original work is properly cited.

Peer-review history:

The peer review history for this paper can be accessed here:
<http://www.sdiarticle4.com/review-history/56918>