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The Study of the Spread of the Novel Coronavirus-19 (COVID-19) in Nigeria Using a Simple Mathematical Model

Ibrahim Shuaibu Ibrahim[1], Salma Aminu Nabegu[2], Farouk Tijjani Sa'ad[3]

[1]Faculty of Medicine, Cyprus International University, Nicosia, Cyprus

[2] Aminu Kano Teaching Hospital, Kano State, Nigeria

[3] Department of Mathematics, Yusuf Maitama Sule University, Kano, Nigeria

Abstract

A simple SEIR model is adopted to study the spread of the novel coronavirus-19 (covid-19) infection in Nigeria. We used data obtained from Nigeria Center for Disease Control (NCDC) as of 29th of June, 2020, to do our numerical simulations and prediction. By means of simulation, the basic reproduction number R_0 for Nigeria happens to be greater than 1, this shows that there is currently covid-19 epidemic in the country. Moreover, the prediction on the nature of the spread of the disease revealed that; in a month's time, the total number of covid-19 positive cases (active cases) would be twice the figure we have now, that is to say around 34,000 active cases. We believe this is related to the population of the exposed class. According to our results, the exposed individuals would reach around 34 million in a month which is way above the figures at the NCDC. By the end of the year 2020, the total active cases are predicted to be more than 1.5 million, which is alarming. Thus, the tracking system of the NCDC and other stakeholders has to be enhanced and readjusted in order to locate, test, isolate, and control this class of people (exposed and infected class).

Keywords: Covid-19, model, NCDC, basic reproduction number.

1 Introduction

The Novel Coronavirus comes from the Coronaviridae family, which primarily causes infections of the respiratory and gastrointestinal tract. It is a zoonotic infection that has gained human to human transmission capability leading to a global health concern. The latest strain described as the "2019 novel coronavirus" also known as the severe acute respiratory syndrome coronavirus 2 (SARS-CoV–2) has ravaged the world at an unprecedented pace causing Coronavirus Disease 2019 (COVID–2019), with clinical symptoms mainly involving dry cough, high fever and shortness of breath and a 2.6 % overall mortality rate [1].

The SARS-CoV–2 was first identified in the city of Wuhan, China in December 2019 causing an outbreak. The outbreak has since spread all over the world from China and causing a pandemic, which was officially declared by the World Health Organization (WHO) on 11 March 2020 [2]. The situation report updated by the world health organization as of 29th June 2020 confirmed 10,021,401 cases with 499,913 deaths globally.

However, in Africa, a total of 303,986 cases and 6,155 deaths have been confirmed with 25,133 cases from Nigeria [3]. Nigeria, also called the giant of Africa recorded its first case on 27th February, a 44-year-old Italian citizen. The case arrived at the Murtala Muhammad airport Lagos on 24th February, traveled to his company site in Ogun state on 25th of February and presented at the staff clinic in Ogun on 26th February with a high index of suspicion by the managing physician. He was referred to Infectious Disease Hospital (IDH) Lagos, where it was confirmed to be Covid-19 on the 27th of February 2020. As of June 29th 2020, there are 25133 confirmed cases with 573 confirmed fatalities and 15158 active cases in 36 states including the federal capital territory (FCT) [4].

Since the confirmation of the first case on 27th February 2020, the NCDC has released advisories and statements to help Nigerians and affected groups in respond to the pandemic. These advisories include, increasing testing capacity by integration of private labs, preventive guidelines for businesses and employers, public awareness and enlightenment on preventive measures, imposing lockdown across the nation, using face masks and so on [4].

NCDC has also released Self-Isolation and Quarantine Guide and Mandatory institutional guideline for returnees to Nigeria to help those who are exposed to COVID-19 confirmed cases or returnees to Nigeria. The Presidential Task Force has published policies and announcements on COVID-19 available on the website of the Presidency – including presidential addresses, task force updates and information on livelihood and economic support [4].

A modeling study Preparedness and vulnerability of African countries against importations of COVID-19 by Marius Gilbert et al. uses data on the volume of air travel departing from airports in the infected provinces in China and directed to Africa to estimate the risk of importation per country. They determined the country's capacity to detect and respond to cases with two indicators: preparedness, using the WHO International Health Regulations Monitoring and Evaluation Framework; and vulnerability, using the Infectious Disease Vulnerability Index. They measure the risk of importation of cases of the novel COVID-19 to African countries from China and was estimated based on origin–destination of air travel flows from the month of January 2019, the number of cases in Chinese provinces and the population in each of the Chinese provinces that reported transmission. Air travel flows counts the number of Origin–destination tickets and account for any connection at intermediate airports. Case data included all confirmed cases recorded until Feb 11, 2020 [5].

A Mathematical model of COVID-19 spread in Turkey and South Africa was studied by Atangana and Araz. They statistically analyzed data from both countries and use the model that takes into account nine classes (susceptible, infected which has 5 sub-classes, recovered, death and vaccinated classes), the parameters were presented and fully explained but the death parameter was removed because it can make the model more complex. The created model includes the lockdown effect, represented by a coefficient that takes into account the social distancing and a contact coefficient. The result shows unfolding of the spread of COVID-19 in both countries has defeated the general expectations that South Africa would record more infections and deaths comparing to Turkey [6].

The statistical analysis results and results they obtained from the suggested mathematical models; indicated that without social distancing restrictions or clear implementation of lockdown regulations, it will be impossible and very hard for countries to control the spread of COVID-19. Therefore, social distancing must be a responsibility of each and every individual living in both countries [6].

Tamer Sanlidag, et al. study and analyze SARS-CoV-2 in Turkish Republic of Northern Cyprus (TRNC) using a mathematical model of the SEIR form. They divided the model into seven distinct compartments including susceptible, exposed, quarantined, SARS-CoV–2 infected with indicated moderate symptoms, infected with severe symptoms, hospitalized, and those who recovered from the disease. In conclusion the designed mathematical model showed the value was continuously calculated in relation to the changing dynamics of the SARS-CoV-2 in Turkish republic of Northern Cyprus. The R_0 value was found to be between 0.68 to 2.35 from11th March to 26thApril, 2020. With the real data giving 0.65 which shows that Turkish Republic of Northern Cyprus is currently free from SARS-CoV-2 and the country will be SARS-COV-2 free [7].

Qianying Lin et al, presented a conceptual model for covid-19 outbreak in Wuhan, China with individual reaction and governmental action. The model successfully captures the course of the covid-19 outbreak and thus, shed light on understanding the trends of the outbreak [8].

Several mathematical models have been used to study the novel coronavirus. They include [9], [10], [11] and so on.

In this work, we adopted a simple SEIR model that will study the dynamics and spread of covid-19 in Nigeria. We aim to collect data from the Nigeria Center for Disease Control (NCDC) and perform simulations and make predictions on what is expected to happen in the future.

2 Mathematical Model Formulation

A simple SEIR model is used to study the dynamics of COVID-19 in Nigeria, and also predict the outcome of the epidemic in the next 200 days. The model is as follows:

$$\frac{dS}{dt} = \alpha - \beta SI - \mu S$$

$$\frac{dE}{dt} = \beta SI - \varepsilon E$$

$$\frac{dI}{dt} = \varepsilon E - \gamma I - \mu I$$

$$\frac{dR}{dt} = \rho I - \mu R$$

where S is the population of susceptible individuals, E are the exposed individuals, I infected individuals, and R are the people recovered from the disease. The total population N is given by $N = S + E + I + R$ and $S(t_0)$, $E(t_0)$, $I(t_0)$, and $R(t_0)$ are all nonnegative. The initial time t_0 is set to be 29th of June, 2020.

2.1 Computation of the Basic Reproduction Number R_0

The basic reproduction number R_0 is computed using the next generation matrix method. The expression of R_0 is as follows:

$$\boldsymbol{R_0 = \frac{\varepsilon\beta\alpha}{\mu(\varepsilon+\mu)(\gamma+\mu)}}$$

Upon substitution of the parameter values in Table 2, the value of the basic reproduction number R_0 is 341.5. This implies that one covid-19 infected person can infect 342 people.

Table 1: Parameter Meanings

Parameter	Meaning
α	Birth rate
β	Infection rate
γ	Death rate due to Covid-19 infection
ε	Rate at which exposed class progress to infected class
ρ	Recovery rate
μ	Death rate

3 Results

We obtain data from the National Center for Disease Control (NCDC) and used it to carry out numerical simulations. The data as of 29th of June, 2020, together with the estimated parameter values of the model are presented in Table 2. The simulation is carried out using Matlab and the results shows that covid-19 infection in Nigeria will keep rising at an alarming rate.

Firstly, upon substitution, the basic reproduction number $\boldsymbol{R_0}$ of Nigeria is found to be 341.5; which is essentially bigger than one. Thus, one covid-19 infected individual can roughly infect a massive 342 susceptible persons. This implies that there is currently covid-19 epidemic in Nigeria.

Table 2: Parameter values

Parameter	Value	Reference
N	206,139,589	National Population Commission (NPC)
$S(t_0)$	206,103,679	
$E(t_0)$	10,777	NCDC
$I(t_0)$	15,158	NCDC
$R(t_0)$	9402	NCDC
α	5.8	NPC
β	0.5944 to 1.68	S. Melliani et al.
γ	0.0378	S. Melliani et al.
ε	1.407	S. Melliani et al.
ρ	0.620	S. Melliani et al.
μ	0.0116	NPC

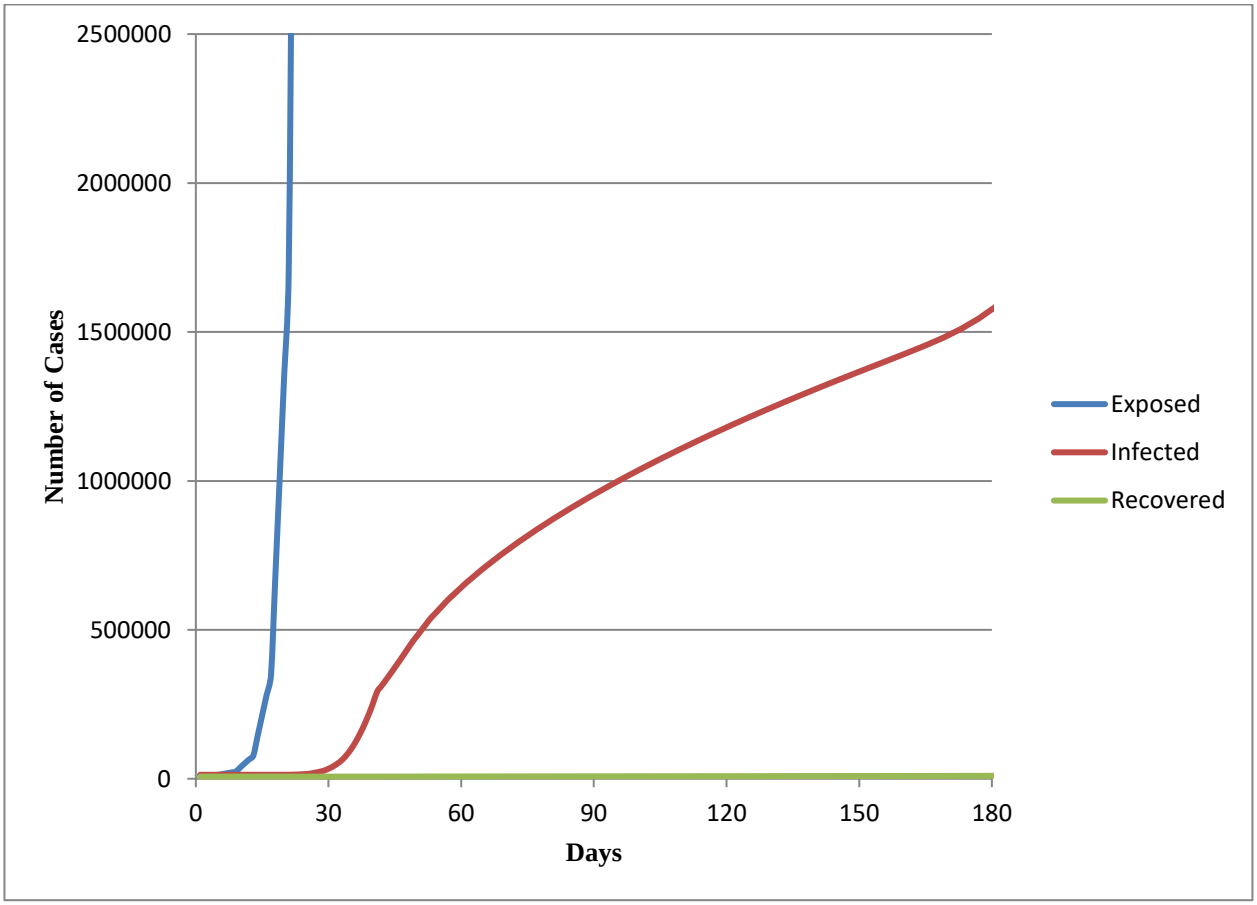

Figure 1: Model Prediction for Nigeria.

Secondly, from Figure 1, the total number of people expected to be infected with covid-19 in a month (July 29th 2020) is 33,518; which is more than doubled the amount we have now. More so, many people are expected to be exposed with the covid-19 virus as the predicted value for the exposed class in a month will be around 35 million. Therefore, the NCDC and other related authorities have to strengthen their tracking system in order to locate, test, isolate, control and quarantine the exposed individuals, because failure to do so will give rise to a dramatic spread of this infectious disease.

By the end of the year 2020, the total number (predicted) of covid-19 positive people will be approximately 1,555,105 as this can be seen in Figure 1. Thus, to avoid this rapid increase, the approach carried out by the authorities in curtailing the spread of Covid-19 in the country has to be reviewed. Efforts have to be doubled, commitment should be improved and other approaches must be employed to address the menace facing the country. The relevant authorities should take the threat of this pandemic more seriously and employ rigorous ways that will stop the spread of the disease.

Our study revealed that the reason behind the increase in infected people may be related with the population of the exposed class. Therefore, the rate at which the exposed class progress to the infected class has to be controlled. Rigorous tracking system has to be adopted in order to trace the people that are exposed with this disease, either by contact with the infected class or by other ways possible.

4 Discussions and Conclusion

We presented a simple SEIR model that studied the dynamics of coronavirus-19 in Nigeria. Data obtained as of 29th June, 2020 from Nigeria Center for Disease Control (NCDC) was used to perform numerical simulations and compute the magnitude of the basic reproduction number for Nigeria. The basic reproduction number $\boldsymbol{R_0}$ is 341.5; which is largely greater than 1. This further implies that one covid-19 positive individual can approximately infect a whopping 342 susceptible individuals. Thus, there is currently covid-19 epidemic in Nigeria and this is a huge concern.

The NCDC data is further used to predict what is likely to happen in the future. In the next 30 days, the total number of active cases is expected to be more than twice the initial value; precisely 33,518 cases. Additionally, it is important to note the exponential increase in the number of exposed individuals. Within a month, the number of exposed people is expected to be around 35 million. This figure is the major contributing factor in the rise of covid-19 infection in the country, because the NCDC don't have the exact figure of the exposed class. As a result, most of them won't be tested or quarantined; as such the NCDC cannot control or doesn't have the track record of the exposed class. Therefore, the increase in covid-19 infection will follow due to the stated reasons.

By the end of 2020, more than 1.5 million people are predicted to be covid-19 positive. Thus, there is need for the NCDC and other concerned agencies to strengthen their efforts and enhance their tracking system so as to avert the menace facing Nigeria. Emphasis should be on revealing the identity of the exposed individuals so that they should be tested, quarantined and controlled.

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