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Assessment of COVID-19 Deaths in Botswana using the SIRD Model for the Period 2020 to 2022

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ABSTRACT

Background: There is need for a development of a robust model framework for COVID-19 to help researchers simulate several virus transmission scenarios, assist in predicting the disease route as well as assess the effectiveness of mitigation measures. COVID-19 data with four compartmental groups, that is susceptible group, the infected group, the recovered group, and the deceased group was required to enable setting up a mathematical compartmental model called Susceptible-Infected-Recovered-Deceased (SIRD) for Botswana. This study aims to set up the SIRD model for COVID-19 in Botswana.
Subjects and Method: The study took advantage of a retrospective cohort study carried out in Botswana specifically from a period ranging from 14th May 2020 to 3rd March 2022. The study population consisted of all persons who are susceptible to COVID-19 in Botswana and the sample size of this study was 2,397,240. Therefore, the variables of interest for this study were susceptible, infected, recovered as well as deceased persons. These were secondary data as reported by Botswana and recorded on the WHO website. Data for this study were analyzed using simulation methods specifically compartmental analysis.
Results: COVID-19 will escalate at a very low transmission at an exponential growth rate of 0.11. The transmission of COVID-19 in Botswana will spread in the population and such spread may cause an epidemic (R0=1.13).
Conclusion: The Ministry of Health and Wellness should ensure that there is slow relaxation of COVID-19 restrictions in order to avoid the reappearance of COVID-19. The Ministry of Health and Wellness should also strictly insist on COVID-19 adherence protocols mainly during the winter season as well as holidays.

Keywords: COVID-19, SIRD model, transmission, epidemic

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BACKGROUND

The Coronavirus disease-2019, abbreviated COVID-19, is an infectious disease caused by the strain called Severe Acute Respiratory Syndrome Coronavirus 2 (SAR-CoV-2) It is simply the respiratory illness that caused the COVID-19 epidemic (Torales et al., 2020; Rehman et al., 2021). COVID-19 is one of the infectious diseases that has infected and affected the human population globally ((CCSA), 2020; Yanez et al., 2020; Obi et al., 2022). The outbreak of the virus was first

discovered in early December 2019 in the City of Wuhan, China and it was reported to WHO on the 31st December 2019 (Torales et al., 2020). Immediately after it was discovered, China was in the spotlight mainly because of the COVID-19 outbreak, a disease defined as a respiratory syndrome (Li et al., 2020). Respiratory syndrome is associated with the wholesale seafood market in Huanan (Chen et al., 2020).

Ever since February 24th, WHO began offering polymerase chain reaction (PCR) kits so that nations can directly test their people for COVID-19. This step was meant to offer nations with capacity to test and detect possible cases before the virus could get out of control (WHO, 2020a). The Director-general of the WHO declared COVID-19 disease as a pandemic on 11th March 2020, stressing that this was the first pandemic caused by a coronavirus (Umviligihozo et al., 2020).

Since the outbreak of COVID-19 in China, the virus affected all the continents leaving behind overwhelming social and economic impacts (Gondwe, 2020). By a year later, the World Health Organization (WHO) reported at least 150 million COVID-19 confirmed cases as well as 3.158 million deaths globally. In addition, America, Europe, and South East Asia emerged as the three leading regions with the highest confirmed COVID-19 infections with 61.9 million, 51.6 million, and 21.8 million, respectively. The African region recorded lower numbers of COVID-19 infections during the same period despite previous statistical models which had projected that the region would be ravaged by COVID-19. The region registered the first case in February 2020 in Egypt. A year later, the number of infections increased to at least 4.5 million, and more than 121 thousand deaths were recorded. In Sub-Saharan Africa (SSA), Nigeria was the first country to register its first COVID-19-positive case on the 27th of February 2020. By April 2021, South Africa the worst-hit country in the SSA region. The country recorded at least 1.5 million COVID-19 infections and over 54 thousand COVID-19 deaths (Agwanda et al., 2021).

After April 2021, the virus spread so extremely and rapidly that WHO had to declare a worldwide emergency amid this pandemic and named COVID-19 (Balkhair, 2020). Different countries across the world had no option but to respond quickly and apply different mitigating measures: movement restrictions, meetings and/or gathering prohibitions, hand-washing, good hygiene promotion, generalized and partial lockdowns (Osseni, 2020). In China, the government decided to issue countrywide guidelines in January 2020 to fight the COVID-19 outbreak (Wang et al., 2021). After strict lockdown measures were implemented in China for more than a month, the government loosened the restriction measures gradually especially on movement beginning of March 2020 (Wang et al., 2021).

The set guidelines were designed to help prevent the spread of COVID-19 infection and were executed by different local health organizations. The public service sectors, for instance, schools and hospitals went through major changes so as to accommodate the new set of guidelines. Both flights and train travel were restricted, and public events were canceled while some of them were postponed. The schools were closed especially in major cities across China (Wang et al., 2021).

The earliest confirmed case of COVID-19 in Botswana was reported and registered on March 30th, 2020 (WHO, 2020b). As a result of the COVID-19 pandemic, the Botswana economy has been harshly impacted. COVID-19 in Botswana has worsened existing growth challenges

which led to an estimated real GDP reduction of 7.9% in 2020 which was the largest record for the country (International Budget Partnership, 2022). According to the COVID-19 brief report (International Budget Partnership, 2022), Botswana's fiscal deficit was set to broaden mainly because of the decline of the mineral revenues as well as the financial impact of spending on the COVID-19 epidemic. The report states that estimates reveal a substantial impact of the COVID-19 pandemic on Botswana's economic viewpoint. This puts the Government of Botswana in a tough position in terms of how it can manage the pandemic.

To understand the course of the epidemic. Mathematical compartmental models for epidemics are the best way to understand the epidemic (Rahman et al., 2021), as the results of such studies may help to prepare control strategies in advance. In particular, the SIRD compartmental model is one such model that has been applied by different researchers to identify the effects of intervention strategies imposed by governments to reduce the COVID-19 infection (Anastassopoulou et al., 2020; Ferrari et al., 2021; Martínez, 2021; Jamil et al., 2022). The SIRD model focuses only on the number of individuals who, are susceptible, infected, and recovered as well as the deceased (Shringi et al., 2024). According to the SIRD model, a susceptible individual who is in contact with an infected individual is prone to get infected by the disease (Anastassopoulou et al., 2020). Moreover, to the best of our knowledge, there has not been any research work of this kind in Botswana, and the present research project seeks to fill this gap. In this study, the researcher aims to set up the SIRD model for COVID-19 in Botswana.

SUBJECTS AND METHOD

1. Study Design

This was of a retrospective cohort study carried out in Botswana specifically from a period ranging from 14th May 2020 to 3rd March 2022 to set up the SIRD model for COVID-19 in Botswana.

2. Population and Sample

The study population was all persons who were susceptible to COVID-19 in Botswana and the sample size was 2,397,270. All persons who were infected and later died as a result of COVID-19 including those who recovered in Botswana were reported to WHO regardless of gender, age and/or any demographic characteristics. The persons were susceptible, got infected, and later on, succumbed to COVID-19 in Botswana.

3. Study Variables

The important variables of this study comprised of susceptible, infected, recovered as well as deceased persons.

4. Operational Definition of Variables

Susceptible: persons who are not infected by COVID-19.

Infected: these are persons with possible symptoms and without symptoms of COVID-19.

Recovered: Persons who are confirmed recovered by the health-care specialist after being infected with COVID-19.

Deceased: these are persons who succumbed to COVID-19 infection.

5. Study Instrument

Data for COVID-19 for persons who were susceptible, infected, and recovered as well as those who succumbed to the virus were obtained from the WHO website

6. Data Analysis

Data for this study were analyzed using a compartmental analysis method where coefficients for the model and other parameters were estimated.

7. Research Ethics

The researcher accessed and retrieved the readily available COVID-19 death statistics on the WHO website specifically for Botswana. The researcher was under any circumstance not able to know the names and other identities of persons who were infected, recovered, or succumbed to COVID-19 disease. The anonymous information helped safeguard the privacy of the deceased persons as a result of COVID-19.

RESULTS

1. Sample Characteristics

The results in Table 1 show a total of 259664, 259304, and 2613 for persons who were infected, recovered, and died respectively between 14th May 2020 to 3rd March 2022. The highest numbers recorded in a week for persons who were infected recovered and died are 15884, 15186, and 269 respectively. On average, 2762, 2758 and 27 persons were infected, recovered, and died respectively with a variation of 3431.59, 3638.46, and 44.43 respectively.

Table 1. Sample descriptive characteristics for 14th May 2020 to 3rd March 2022 SIRD data (N=2,397,240)

Characteristics	Range	Minimum	Maximum	Sum	Mean	SD
Susceptible	30,466	2,366,774	2,397,240	224,818,979	2391691.27	6935.07
Infected	15,884	0	15,884	259,664	2762.38	3431.59
Recovered	15,186	0	1,5186	259,304	2758.55	3638.46
Deaths	269	0	269	2,613	27.80	44.43

2. Compartmental analysis Fitting the SIRD model

Figure 1 depicts the normal way in which susceptible rate, infected rate, recovery rate, and death rate evolve in an epidemic situation. The recovery rate can possibly change through the course of the epidemic. The change is influenced by interventions such as effective medical treatments, the collapse of the healthcare system, or when some patients are discharged from healthcare facilities. The recovery rate rises at the begining of the epidemic and then rises as the epidemic progresses. The results show that the death rate constantly increased from 0 whereas the infected rate remained constant from week 51. The weekly dynamics are shown in Table 1.

a. Parameters of the SIRD model

The SIRD model depends only on three coefficients namely the transmission rate for every unit of time (β), the recovery rate for every unit of time (γ) and the death rate for every unit of time (δ). In this regard, the coefficients of the SIRD model are 1.00, 0.28, and 0.61 for an infected or transmission rate for every unit of time, the recovery rate for every unit of time, and the death rate for every unit of time-respectively. This implies that a total of 100% of persons who are infected will transmit the COVID-19 disease, about 28% will recover per unit of time whereas 61% of persons are expected to succumb to COVID-19 disease.

b. The Exponential growth rate

At the initial phase of the epidemic the susceptible (S) is approximately equivalent to the population (N). The exponential growth rate is denoted by r_0. According to the r_0, the epidemic increases in the population when the growth rate is more than zero. On the other hand, the growth rate decreases when it is less than the value of zero. The results showed that the epidemic would increase in the population though at a very low transmission (0.11).

c. The Reproduction Number (R_0)

The R_0 is applied to predict whether COVID-19 infection would spread in the population or would consequently die out. This number helps to determine the severity of the COVID-19 outbreak. Furthermore, the reproduction number assesses both the strengths of medical facilities and the necessary behavioral interventions. The results revealed the R_0 (1.13) which is greater than 1. It is therefore clear that the transmission of COVID-19 in Botswana will spread to the population. The same R_0 (1.13) also indicates that as COVID-19 spreads in the community, such spread may cause an epidemic. In addition, the number further shows that any person infected by COVID-19 is expected to spread the virus to at least one person on average.

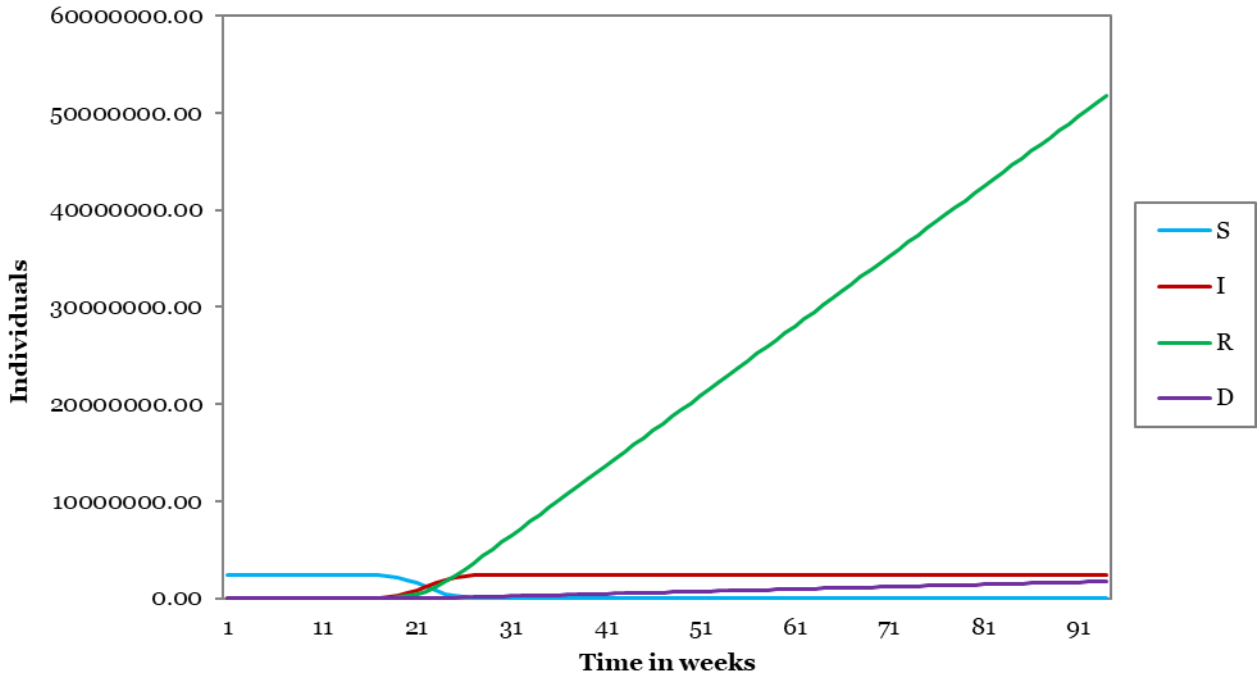

Figure 1. Weekly epidemic dynamics of the SIRD model

DISCUSSION

Whilst the findings of this study revealed that 100% of persons who are infected will transmit the COVID-19 disease to other persons, the study (Martínez, 2021) found that approximately only 11% of persons were perhaps infected without quarantine and isolation measures. This study found that the reproduction number is estimated at 1.13 indicating that any person infected with COVID-19 is expected to spread the virus to at least one person on average. The estimated value (1.13) is lower than those estimated in Russia (1.30), India (1.26), France (2.72), USA (1.61), Syrian Arab Republic (2.80), and Yemen (1.41) but higher for those reported in Nigeria (1.01) where the same model was applied (Lounis and Al-Raeei, 2021).

This study through the reproduction number which assessed both the strengths of medical facilities and the behavioral interventions revealed that the transmission of COVID-19 in Botswana will definitely spread in the population. On the other hand, Ferguson et al. (2020) and Peak et al. (2020) found that timely implementation of non-pharmaceutical interventions such as lockdown measures and social distancing could meaningfully lessen transmission

rates. These would then translate to the alleviation of strain on healthcare systems. In a study carried out by Chinazzi et al. (2020), the authors applied a SIRD model and anticipated the possibility of COVID-19 spreading in the populace. The authors made more emphasis on early intervention strategies, for instance, rapid testing and travel restrictions. In comparison, this study revealed that the epidemic would increase in the population though at a very low transmission and the transmission may increase if COVID-19 protocols are not adhered to.

One of the limitations of this study was the swift development of the virus, which could render findings out-of-date due to other emerging new variants. The variability in testing procedures for the virus and the study population could lead to inconsistencies in the results, which certainly could hamper the generalisability of the findings. As a final limitation, the long-term effects of the virus continue to be uncertain and this requires continued studies to completely understand the effects of the virus on global health.

In conclusion, the study provided a vital understanding of the nature of the COVID-19 virus and the transmission dynamics of the virus. Through the rigorous inquiry using the model, crucial information has been recovered and this would play a pivotal role in guiding health interventions.

The Government through the Ministry of Health and Wellness should ensure that there is unhurried relaxation of COVID-19 restrictions and also inspire adherence to the public during the winter season and holidays. These measures would have more benefits, especially in ensuring that the virus does not reappear.

AUTHOR CONTRIBUTION

The author made a significant contribution to the article from data collection and writing the whole manuscript reviewing as well as editing at the final stage.

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Nill.

CONFLICT OF INTEREST

There are no conflicts of interest.

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