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Analysis and forecasting of confirmed, death, and recovered cases of COVID-19 infections in Nigeria

Implications for university administrators

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Abstract

The coronavirus (COVID-19) disease outbreak was a public health emergency of international concern which eventually evolved into a pandemic. Nigeria was locked down in March, 2020 as the country battled to contain the spread of the disease. By August 2020, phase-by-phase easing of the lockdown was commenced and university students will soon return for academic activities. This study undertakes some epidemiological analysis of the Nigerian COVID-19 data to help the government and university administrators make informed decisions on the safety of personnel and students.

The COVID-19 data on confirmed cases, deaths, and recovered were obtained from the website of the Nigerian Centre for Disease Control (NCDC) from April 2, 2020 to August 24, 2020. The infection rate, prevalence, ratio, cause-specific death rate, and case recovery rate were used to evaluate the epidemiological characteristics of the pandemic in Nigeria. Exponential smoothing was adopted in modeling the time series data and forecasting the pandemic in Nigeria up to January 31, 2021.

The results indicated that the pandemic had infection rate of at most 3 infections per 1 million per day from April to August 2020. The death rate was 5 persons per 1 million during the period of study while recovery rate was 747 persons per 1000 infections. Analysis of forecast data showed steady but gradual decrease in the daily infection rate and death rate and substantial increase in the recovery rate, 975 recoveries per 1000 infections.

In general, the epidemiological attributes of the pandemic from the original data and the forecast data indicated optimism in the decrease in the rate of infection and death in the future. Moreover, the infection rate, prevalence and death rate in January 2021 coincided with the predictions based on the analysis. Therefore, the Nigerian government is encouraged to allow universities in the country to reopen while university administrators set up the necessary protocols for strict adherence to safety measures.

Abbreviations: CDC = Centre for Disease Control and Prevention, COVID-19 = 2019-nCoV coronavirus disease 2019, CSDR = cause-specific death rate, case recovery rate, NCDC = Nigerian Centre for Disease Control, WHO = World Health Organization.

Keywords: death rate, forecast, infection rate, prevalence, recovery rate, university administrator

1. Introduction

The novel Coronavirus infection, commonly called COVID-19, was caused by the severe acute respiratory syndrome coronavirus 2, Sars-Cov-2 virus.[1–4] The virus disease, characterized by severe acute respiratory pneumonia symptoms, was first reported in Wuhan, in the Hubei province of China in late 2019, according to reports.[5] The outbreak of the virus infection, of devastating and unpredictable dimensions, was declared a pandemic by the World Health Organization (WHO) in March, 2020 as the virus disease spread and ravaged many countries of the world.[6–8] The COVID-19 pandemic, according to WHO,[9] has affected over 200 countries, infecting approximately 29 million persons and claiming about 0.9 million lives as on September 14, 2020 with attendant economic, social, and health consequences.

The first confirmed case of the virus infection was reported in Nigeria on February 27, 2020, which spread rapidly to several states, cities, and provinces of the country.[10] The Nigerian government enforced general lockdown in March, 2020, among other restrictions, in the bid to contain, control, and minimize the number of infections, deaths, and impact of the disease. Easing of the lockdown was extended more than 2 times as the number of infections and fatalities by the disease grew. By August 2020, the federal government of Nigeria gradually eased the lockdown as interstate movements resumed and exiting students were allowed to write their external examinations under strict safety measures. However, schools, offices, and international flights are yet to reopen as at the time of this research report.

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The datasets generated during and/or analyzed during the current study are publicly available.

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As the federal government of Nigeria mulls the reopening of schools,[11] it is imperative to adequately evaluate the Nigerian coronavirus data with the view to appropriately understand the epidemiological characteristics and the implications as students travel from different parts of the country back to their academic institutions. Since the outbreak of the disease, efforts have been made to use mathematical and statistical approaches to analyze and model the behavior of the disease to ensure adequate planning, control, and implementation of safety measures and social interventions.[4,5,10,12–21] Wolkewitz and Puljak[22] discussed some of the methodological challenges in producing, gathering, analyzing, and reporting data related to the pandemic and emphasized the need for quality and sufficient data.

Survey studies have been conducted and mathematical models developed to describe the Nigerian COVID-19 outlook while predictions were made based on the models and survey outcomes.[10,23–26] Most of these studies were conducted at the onset of the virus infection in Nigeria with scanty data of which the outcomes captured gloomy future health indices for Nigeria and do not necessarily reflect the realities several months after. This study evaluated detailed epidemiological attributes of the COVID-19 infections in Nigeria from information gathered for a period of 131 days from the website of the Nigerian Centre for Disease Control (NCDC). Comparison was made of the attributes of the infectious disease within the study period and the forecast period, up to January 31, 2021, using forecast data. The results of this study give better and clearer view of the future outlook of the pandemic in Nigeria as universities prepare to resume and students return for academic activities.

2. Methodology

The source and method of data collection as well as the various epidemiological and time series methods used in the analysis and forecasting of the COVID-19 data for Nigeria are described in this section. This study involved information/data freely available in the public domain/database of the Nigerian Centre for Disease Control (NCDC) and there is no risk of possible disclosures as the data is neither sensitive nor confidential. The data collection does not require any participants, identification of participants, physical contact with participants, or any form of discomfort/risk to participants. Therefore, ethical approval was not necessary.

2.1. Data collection and description

The data used for this study are the cumulative and daily confirmed cases, deaths, and recoveries from the disease outbreak in Nigeria published by the Nigerian Centre for Disease Control (NCDC).[27] NCDC is the agency appointed by the Federal Government of Nigeria to oversee and implement the activities of the government in the management and control of the COVID-19 outbreak in Nigeria. The data was collected for a period of 5 months, from April 5, 2020 to August 24, 2020, a total of 131 days. The cumulative records of infections, deaths, and recoveries before April 5, 2020 were also included in the data.

2.2. Epidemiological analysis

The infection rate, death rate, recovery rate, prevalence, and ratio are the epidemiological statistics utilized to help measure and understand the attributes of the novel coronavirus infection in Nigeria. The rate of infection is the measure of the risk of the disease or probability of getting the disease.[28] It is calculated as

$$\text{Rate of infection} = \frac{\text{Number of Infections}}{\text{Total population at the onset of the disease}} \times 10^n, \quad (1)$$

where considering the size of the population of Nigeria, n is assumed to be 5 such that 10^5=1,000,000 displays the rate of infection per 1million persons in the country. The denominator considers only the population at risk of contracting the COVID-19 infection. The numerator for the infection rate is the total number of infections from the onset of the infection to the last day of the study, while the denominator is the population of Nigeria at the onset of the disease. From the World Population Review,[29] the 2020 population of Nigeria is approximately 206 million. Also the daily infection rate was obtained to ascertain the rate of the virus infection on the Nigerian population per day. The numerator for the daily infection rate is the number of new cases for each day. The denominator varies by day since it is the total number of the population at risk of getting the disease. Each number of new cases of a particular day is subtracted from the population for that particular day to obtain the population at risk for the next day. This is because any member of the population that have contacted the disease is no longer at risk of the contagion and therefore, removed from the at-risk population.[28] For instance, the population at risk for the second day is the population (206,139,349, after removing the 243 recorded before the study period) at the first day of the study minus the number of infections (130) on the first day. This gives 206,139,216 as the at-risk population for the second day. The complete computations for the daily infection rates are displayed in Table S1, Supplemental Digital Content, http://links.lww.com/MD/G308.

The prevalence of the disease is the proportion of individuals in the population who have contacted the COVID-19 disease at a specific time (day is used as time in this study) or over the specified period,[28] which, in this study, is the 131 days of data collection. Therefore, the prevalence of the disease is given by

$$\text{Prevalence} = \frac{\text{All new and pre} - \text{existing cases during the period}}{\text{Population during the time period}} \times 10^n. \quad (2)$$

The multiplier, 10^n=1,000,000 for n=5, which reflects the prevalence of the infection per

1million persons in the Nigerian population. Point and period prevalence of the disease in Nigeria were computed. Point prevalence was obtained to ascertain the daily prevalence of the disease, while period prevalence described the overall prevalence of the disease over the 5-month period. The numerator for the point prevalence is simply made up of the new confirmed cases for the day and preexisting number of cases before each specific day. Therefore, it is the daily cumulative of the confirmed cases. The denominator remains the population of Nigeria at the onset of the disease. Obtaining the point prevalence is important in assessing the daily prevalence of the disease in Nigeria. The detailed results of the point prevalence are presented in Table S2, Supplemental Digital Content, http://links.lww.com/MD/G308. Period prevalence was computed using the overall cumulative of confirmed cases of the disease from the time the first case was reported. Therefore, the numerator is the total of the cumulative confirmed cases on the last day of data collection, while the denominator is

the population of Nigeria at the onset of the disease. The period prevalence helps to determine the overall prevalence of the COVID-19 infection in Nigeria.

The death-to-confirmed ratio, recovered-to-confirmed ratio, and death-to-recovered ratio were ascertained using Eq. (3). In this way, the exact number of deaths for each confirmed case, exact number of recovered cases for each confirmed case, and the exact number of deaths for each recovered case were ascertained as the ratio statistics of the COVID-19 outbreak in Nigeria. The ratio was computed as[30]

$$\text{Ratio} = \frac{\text{Total case of variable 1}}{\text{Total case of variable 2}}, \tag{3}$$

where numerator for death-to-confirmed in Eq. (3) (that is, variable 1) is the total number of deaths while the denominator (variable 2) is the total confirmed cases, and so on. This makes it possible to obtain the appropriate number of cases of variable 1 for each case of variable 2.

Also, the cause-specific death rate (or cause-specific mortality rate) was obtained for the COVID-19 pandemic in Nigeria. According to CDC,[28] the cause-specific death rate (CSDR) measures the deaths in a population attributed to a specific cause. In this case, the cause-specific death rate was used to determine the rate of death in the Nigerian population caused by the coronavirus (COVID-19) pandemic. From Mardones,[31] the specific death rate is calculated as

$$\text{CSDR} = \frac{\text{Total number of death in given time due to the disease}}{\text{Total population at risk}}. \tag{4}$$

CSDR is expressed as whole number by multiplying by 1 million to obtain the number of deaths per 1 million persons in the at-risk population. The denominator is the total population of Nigeria at the onset of the pandemic which is specifically 206,139,589. In this way, the rate of death in the Nigerian population as a result of the COVID-19 pandemic is ascertained.

Furthermore, the case recovery rate (CRR) was computed to determine the rate of recovery from the COVID-19 infection in Nigeria. The rate of recovery from the case of COVID-19 infection is actually the proportion of total number of recoveries and total number of confirmed infections at given time in the population.[31] Therefore, the case recovery rate is calculated as

$$\text{CRR} = \frac{\text{Total number of recovered}}{\text{Total number of confirmed cases}}. \tag{5}$$

The recovery rate is multiplied by 1000 to obtain the rate of recovery for every 1000 infections in Nigeria since the total infection in Nigeria at the time of this report was not up to a hundred thousand. The infection rates, prevalence, ratios, death rate, and rate of recovery were computed by adopting Eqs. (1), (2), (3), (4), and (5), respectively, in Mathematica version 11.3.

2.3. Time series analysis

Having collected, from the Nigerian Centre for Disease Control (NCDC), substantial data on the cumulative and daily confirmed cases, deaths, and recoveries from COVID-19 in Nigeria, time series analysis was performed on the data to model the disease in Nigeria and forecast new cases, deaths, and recoveries in the near future. Since there is no clear seasonality in the data, exponential smoothing was employed for the modeling and forecasting of the cumulative cases, daily confirmed cases, cumulative deaths, daily deaths, cumulative recoveries, and daily recoveries from the COVID-19 infection. According to Hyndman and Athanasopolous,[32] models and forecasts produced using exponential smoothing are weighted averages of past observations, with the weights decaying exponentially as the observations get older. This weighting framework is a major advantage and of great importance to the method as it produces reliable forecast for a wide range of time series. The Brown exponential smoothing in the JMP statistical software was used in the time series modeling and forecasting in this study and the functional form, as given by Hyndman and Athanasopolous,[32] for modeling and forecasting of the infection variables in Nigeria, is

$$\hat{y}_{T+1|T} = \sum_{j=0}^{T} \alpha(1-\alpha)^j y_{T-j} + (1-\alpha)^T \ell_0, \tag{6}$$

where $\hat{y}_{T+1}$ is the estimate of the observations in the series, $y_1, ..., y_{T-1}; 0 \leq \alpha \leq 1$ is the smoothing parameter, and ℓ_0 is the first fitted value at time, 1. The smoothing parameter is estimated using the mean square error (MSE) which ensures the precision of the forecast estimation.[33]

The forecast period was extended to January 31, 2021, covering a period of 160 days from the last day in the data set, which is August 24, 2020.

The time series plots or time plots for each of the cumulative and daily confirmed cases, deaths, and recovered cases were obtained, as well as the model R-square and parameter estimates using JMP version 14 software. The adequacies of the models were ascertained using the coefficient of determination (R-square) and the significance of the parameter estimates. The R-square should be close to 1.0.

The time plot is the plot of the observations such as the confirmed cases, deaths, and recoveries against the time the observation was made, where consecutive observations are joined by straight lines.[28] The time plots were used to reveal the features about the COVID-19 infection records in Nigeria. The P value of the t test for the significance of the model parameter should be less than 0.05 ($P < .05$) for the parameter of the model to be significant.

3. Results

3.1. Summary descriptive statistics

The summary descriptive statistics, minimum, maximum, sum, mean, and standard deviation, for the daily new confirmed cases, daily deaths, and daily recovered cases are displayed in Table 1. The variables, new confirmed cases, daily deaths, and daily recovered are, respectively, the number of people who were confirmed with the infection, died, or recovered from the COVID-19 infection daily. The minimum statistic is simply the lowest number of cases per day, while the maximum statistic is the highest number of cases per day. The sum statistic is the total number of cases for the period under study which is obtained by adding (cumulative of) all the daily recorded cases throughout the period. The mean is obtained for each variable (new confirmed

Table 1

Summary descriptive statistics.

	N	Minimum	Maximum	Sum	Mean	Std. deviation
New confirmed cases	131	34	790	52,137	397.99	185.287
Daily death	131	0	45	1028	7.85	6.202
Daily recovered	131	0	11188	45,861	350.08	1159.455

cases, daily deaths, and daily recovered) by dividing the sum for each variable by N, the total number of days of the study. The mean indicates the average number of new confirmed cases, deaths, and recoveries per day. The standard deviation shows the dispersion between the daily cases (confirmed, death, or recovered) and the mean. It is obtained as the sum of the squared differences between the daily cases and the mean divided by N. The bigger the standard deviation, the larger the dispersion between the mean and the daily cases and vice versa.

The total of the daily confirmed cases which is 52,137 excluded the 243 aggregate laboratory confirmed cases from February 27, 2020 when the first (index) case was reported in Nigeria, up to April 1, 2020, before the collection of the data used for this study started. Daily deaths and daily recovered with minimum of "0" indicate that there were days no death was recorded or no body recovered (recovered here implies discharged from the hospital or certified free of the virus). There is an average of 398 new infections, average of 8 deaths and average of 350 recoveries per day, from April 5 to the last day of data collection, August 24, 2020. Note that the sums of daily deaths and daily recovered did not add up to the sum of new confirmed cases because there is number of the COVID-19 patients who have neither recovered nor died.

3.2. Epidemiological analysis

The results of the overall rate of infection, prevalence, cause-specific death rate (CSDR), and case recovery rate (CRR) are presented in Table 2. The result indicates that the rate of the infection in Nigeria from April 2, 2020 to August 24, 2020 is approximately 3 persons per 1million persons in the population. This means that 3 persons out of every 1 million persons in the Nigerian population are at risk of contracting the COVID-19 infection during the specified period. The denominator reflects the population at the risk of contracting the infection from April 2, 2020 after adjusting the population for the 243 that have already contracted the infection by April 1, 2020.

The results of the daily infection rates of the COVID-19 in Nigeria are displayed using the graph in Figure 1 for the 131 days. From Figure 1, the daily infection rate of the COVID-19 pandemic on the Nigerian population did not exceed 3 infections per million persons per day. There were 3 infections per million per day for only 15 days out of the 131 days but this was not observed in the last 30 days of the study period, starting late July, 2020. The daily infection rate for the last 30 days was fluctuating between 1 and 2 infections per million persons per day. The infection rate for the first 13 days, which corresponds to the middle of April, 2020, was less than 1 infection per million persons per day.

The period prevalence of the COVID-19 infection in Nigeria for the 131 days, as shown in Table 2, indicates 255 infections per 1 million persons in the population during the period under study. This implies that 255 persons per 1 million in the population contracted the infection from February 27, 2020, when the first case was confirmed up to August 24, 2020. The point prevalence, which was used to describe the daily prevalence of the infection per 1 million persons in the population, is presented in the second plot of Figure 1 for the 131 days the data were collected. The point prevalence displayed the number of infected persons in every 1 million persons in the population per day. The graph showed steady and sustained increase in the daily prevalence of the COVID-19 infection in Nigeria. The prevalence started with about 1 to 2 infections per 1 million persons per day in the first 6 days at the onset of the study and ended with over 200 infections per 1 million persons per day in the last 25 days of the study period. This indicates that the prevalence pattern is the cumulative of the daily prevalence. Therefore, as long as there is at least 1 new infection in a day, the daily prevalence of the infection will keep increasing, unless no new cases are observed.

With a total of 1004 deaths by August 24, 2020, the Nigerian cause-specific death rate (CSDR), as shown in Table 2, is 4.870486. Therefore, there are 5 deaths per 1 million persons in the population caused by the infection from the time of the first confirmed case in February to August 24, 2020. Also, the case recovery rate of the population infected by the COVID-19 disease is 747.1074 per 1000 persons. This value implies that there are 747 recoveries in every 1000 infections in Nigeria. The recovery

Table 2

Epidemiological attributes of the COVID-19 infections in Nigeria.

Statistic	Value	Estimated from
Infection rate	2.549 per million	Equation (1)
Prevalence	254.91 per million	Equation (2)
CSDR	4.870486 per million	Equation (4)
CRR	747.1074 per thousand	Equation (5)

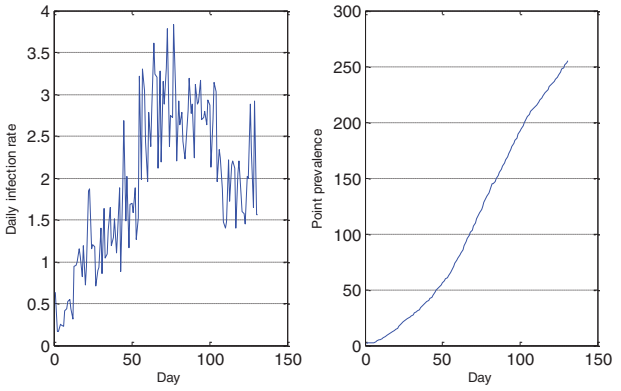

Figure 1. Infection Rate and Point Prevalence of COVID-19 Per 1 Million Persons in Nigeria. Graph 1, infection rate fluctuates between 0.2 (first 3 days) and 3.8 (on 77th day) during the study period. Graph 2, point prevalence keeps increasing so long as there is at least 1 additional confirmed case.

Table 3

Ratio statistics.

Confirmed case: 51	New death: 1
Confirmed case: 1	New recovered: 1
New recovered: 45	New death: 1

rate is impressive considering the fatal nature of the COVID-19 pandemic.

3.3. Ratio statistics of the COVID-19 infection

The ratio statistics for the COVID-19 infection variables (confirmed cases, deaths, and recoveries) are displayed in Table 3. The ratio of confirmed new cases to deaths and recovered shows that there is 1 death for every 51 confirmed cases; 1 death for every 45 new recovered cases, and 1 recovered case for every 1 confirmed case.

3.4. Time series results

The time plot of each of the variables, confirmed cases, daily confirmed cases (that is additional confirmed cases), deaths, daily deaths (additional deaths), recovered, and daily recovered (additional recovered) are displayed in the plots of Figure 2. The horizontal axis of the plots represents "day" while the principal axis represents the variable. The plots for cumulative confirmed cases, cumulative deaths, and cumulative recovered, respectively, show steady rise in the number of confirmed cases, deaths, and recovered. This is expected since the variables are the cumulative cases and will only keep increasing so long as there are new confirmed, death, and recovered cases, which was the situation throughout the 131 days of data collection. However, the plots did not indicate any seasonal patterns.

The time plots of the additional (daily) confirmed, deaths, and recovered cases displayed fluctuations, indicating the random increase and decrease in the number of cases per day. The graph of cumulative death is more tilted than the graphs of cumulative confirmed and cumulative recovered cases, which points to the fact that the death rate is lower than the infection rate and the recovery rate. It could be observed that the graphs of the cumulative confirmed and cumulative recovered cases almost have the same line pattern, which points to the equivalence ratio of 1 confirmed case to 1 recovered case. The graph of the daily confirmed cases showed that there was as low as less than 100 confirmed cases a day in the first 20 days at the onset on the infection and up to 800 confirmed cases a day around the 100th days of the pandemic in Nigeria. The graph of the daily (additional) deaths showed that slightly more than 40 deaths were recorded in a day at the early days of the pandemic but mostly the number of deaths per day is less than 5. The graph of the daily recovered cases was more stable than the others with the number of the daily recovered fluctuating between zero (at the early days of the infection) and 200 cases with but with somedays exceeding 5000 recovered cases.

The R-square statistic and parameter estimate of each of the models describing confirmed cases, additional confirmed cases, deaths, additional deaths, recovered, and additional recovered are presented in Table 4. All the model parameters, except that of additional recovered, are significant at 0.05 level of significance under simple exponential smoothing but only the R-square of the additional death model and additional recovered model are small. These results indicate that simple exponential smoothing is adequate to model and forecast 5 out of the 6 variables. The double exponential smoothing, which gave significant model parameter value, as shown in column 7 of Table 4, is adequate to model and forecast the additional (daily) recovered cases.

3.5. Forecasting

The forecasts of the COVID-19 confirmed, additional confirmed, deaths, additional deaths, recovered, and additional recovered cases in Nigeria spanned a period of 160 days, from August 25, 2020 to January 31, 2021. The extended forecast period is to help monitor the behavior of COVID-19 pandemic in Nigeria in the near future with respect to the 6 variable as the government mulls opening of schools, offices, international flights, and relaxing of

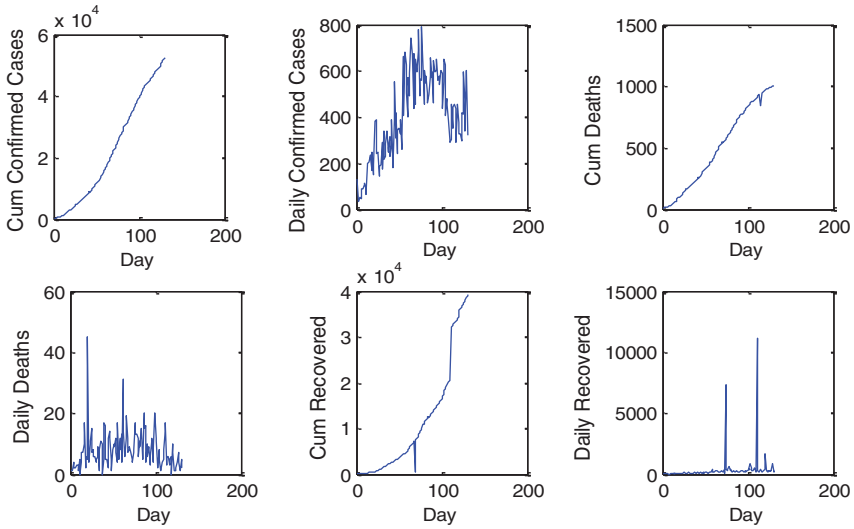

Figure 2. Time Plots of COVID-19 Infections in Nigeria. Plots 1, 3, and 5 are cumulative confirmed, death, and recovered cases, respectively, which will keep rising as long as there is at least 1 new confirmed, death, or recovered cases. Daily confirmed, deaths, and recovered cases in plots 2, 4, and 6, respectively, have no specific pattern.

Table 4

Model summary and parameter estimates.

Model	R-square estimate	Std error	t Ratio	Prob>|t| (simple)	Prob>|t| (double)
Confirmed cases—Model 1	0.999685 1.71235170	0.0507037	33.77	<0.001*	
Additional confirmed—Model 2	0.721123 .30508123	0.0611139	4.99	<0.001*	
Deaths—Model 3	0.997829 .97445539	0.0690918	14.10	<0.001*	
Additional deaths—Model 4	0.049924 .12818654	0.0514423	2.49	0.014*	
Recovered—Model 5	0.987803 .87470106	0.0792989	11.03	<0.001*	
Additional recovered—Model 6	0.021563 .03514282	0.0229355	1.53	0.123	<0.002*

* Significant at 0.05 level of significant.

restrictions. The results for confirmed, additional confirmed, deaths, additional deaths, recovered, and additional recovered are displayed in the time plots of Figure 3. There is steady decrease in the number of additional (daily) confirmed cases while additional (daily) deaths are about 3 per day on the average. The number of additional recovered cases fluctuates between 250 and 450, with most of the daily recoveries being around 350. The confirmed, deaths and recovered displayed steady increase, which is expected since there are still records of daily confirmed, deaths and recoveries.

The daily infection rate per million was also computed from the forecast data of the additional confirmed cases using Eq. (1). The population at risk (206,135,157) for the first day of the forecast was obtained after deducting the total already infected persons from the Nigerian 2020 population (206,139,589) at the onset of the disease. Figure 4 is a plot of the daily infection rate of the COVID-19 infection per million persons of the at-risk population within the forecast period. The plot shows steady decline in the daily infection rate. There is at most 1 infection per 1 million persons per day and the rate drops below 1 person per million from early January 2021.

The forecast results do not give depressingly gloomy information about the future infection, death, and recovery from the COVID-19 infection in Nigeria as predicted in some studies.[9] These are indications that the infection has been contained and could be adequately controlled in the near future.

Furthermore, since the forecast period covered a period of 160 days, the cause-specific death rate (CSDR) from the forecast data is 3 persons per 1 million persons while the case recovery rate (CRR) is 975 persons per 1000 infections during the forecast period. Also, the total number of deaths from the infection during the forecast period is 664 while total recoveries are 62644. With strict enforcement of the safety measures, social distancing, wearing of facemask, regular washing of hands with hand sanitizer, and so on, outlined by the World Health Organization (WHO), the Nigerian government could be encouraged to allow for reopening of schools, markets, offices, international flights, etc.

4. Discussion

The data used in this study are limited to only the cases in hospitals or at home brought to the notice of the Nigerian Centre for Disease Control (NCDC), as there may be COVID-19 cases that could not reach hospitals due to lockdown or some other factors. Since these other cases were not captured in NCDC database and are not known, they were excluded from the study. With substantial data on the COVID-19 cases in Nigeria

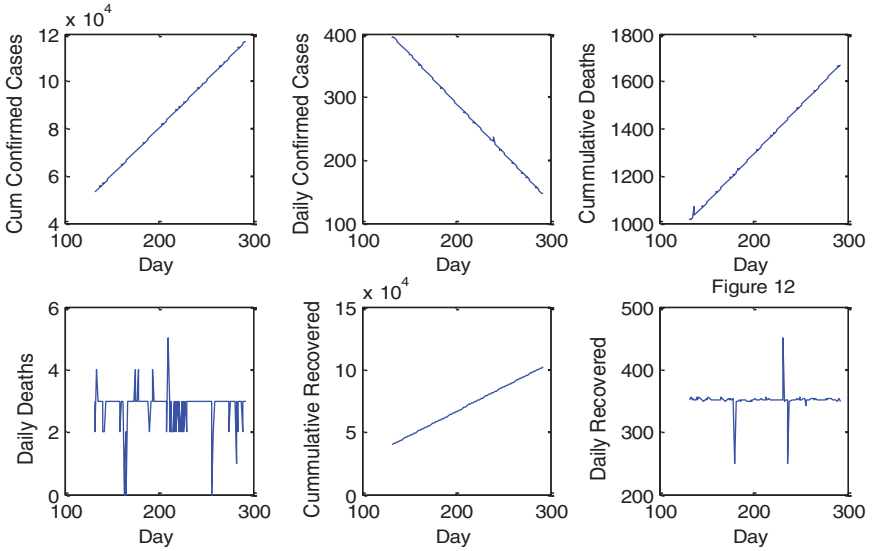

Figure 12

Figure 3. Time Plots of COVID-19 Cases from Forecast Data. The cumulative confirmed, death, and recovered keep rising for every additional case in plots 1, 3, and 5. Daily confirmed cases keep reducing to below 200 cases per day toward the end of the forecast period. Deaths fluctuate between zero and 5 at the early stage of the forecast and narrow to 1. There is average of 350 daily recovered.

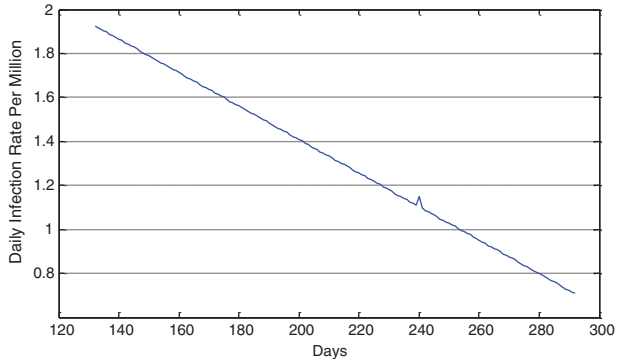

Figure 4. Daily infection rate from forecast data. Daily infection rate drops to below 1.0 in the last 30 days of the forecast period.

collected for a period of 131 days on the confirmed cases, deaths, and recovered cases in Nigeria, some epidemiological analysis has been performed on the data to better appreciate the characteristics of the disease. Time series modeling of the infectious disease data and forecasting were also performed. These are very important in evaluating the risk of the infection, ascertaining the burden of the disease, planning for preventive actions, planning for future needs, and setting the priorities on health research and development. Also, this provides the necessary guide in assessing the health, economic, and social impact of the infection on the Nigerian population.

The daily infection rates and daily prevalence of the disease in Nigeria up to August 2020 show that the COVID-19 infection has not been very severe in the country. There were 3 persons in every 1 million at risk of contracting the COVID-19 infection in Nigeria during the specified study period at the rate of at most 3 infections per day. During this study period, the prevalence of the infection was 255 infections per million persons in the population. Five deaths per 1 million persons in the population were estimated from the time the first case was recorded, February, 2020, to the last day of data collection, August 24, 2020. The recovery rate from the COVID-19 infection, estimated at 747 recoveries per 1000 infections, is remarkable considering how lethal the infection has proved to be. These statistics improved remarkably within the 131 days forecast period. The forecast data, up to January 31, 2021, show steady decline in the number of daily infections, number of deaths, and reduction in the specific death rate. Also, the rate of recovery from the forecast analysis improved substantially to almost 98% of the confirmed cases. Moreover, based on the analysis, the infection rate, recovery rate, prevalence, and death rate in January 2021 coincide with the predictions. These are indicators that the spate of infections and related deaths have been adequately contained in Nigeria. Most of the reports on COVID-19 in Nigeria were published before the infection peaked in Nigeria and therefore do not provide clear view of the situation in Nigeria.[10,23,25,34,35] The fluctuations in the number of infected cases reported in these studies during the early days of the infection in Nigeria without definitive long-term outlook are evidence of the limitations of the short-term data. However, the findings and recommendations of these studies agreed with the control of the pandemic in Nigeria projected from the forecast data of this study but on the premise that the recommended safety guidelines are implemented and sustained, which is true. The only insight into the long-term record of the pandemic in Nigeria was through the simulation study by Iboi et al. in 2020. The simulation study spanned a period of about 8 months, up to January 2021. It was projected that the pandemic will be contained in Nigeria with moderate or strict implementation of physical distancing and not lifting of lockdown early. The daily 3900 infections by August, 2020 under mild physical distancing measures, according to the projection by Iboi et al. in 2020 fell flat as the government began stage-by-stage lifting of the lockdown by middle of August, 2020 as the number of infections and deaths declined.

University administrators are trained and knowledgeable individuals who direct the affairs of a university in such a way as to achieve the primary goals and objectives efficiently. Some of the university administrators in the Nigerian university system include the vice-chancellors, deputy vice-chancellors, registrars, librarian, among others. These are the people concerned with the management and control of COVID-19 infection in the universities following lifting of the lockdown by the Federal Government of Nigeria. Though the results of the analysis and forecast of the COVID-19 infection indicate that the infection rate, prevalence, and death rate by the infection is on decline while the recovery rate in on the increase; there is still need to adopt the safety measures stipulated by the WHO and NCDC. To this end, the implication of this study for university administrators cannot be overemphasized. They need to be involved in enlightenment campaign programmes organized by the government on the control of the disease. This will equip them on how best to handle the control of the COVID-19 in schools when the schools reopen. If not properly managed, COVID-19 could have far-reaching negative consequences. Such measures include regular washing of hands with alcohol-based hand sanitizers; avoiding crowded places; maintaining at least 1 m social distancing; wearing of face mask; adopting good respiratory hygiene; avoid touching of the eyes; nose and mouth, among others. Based on these, the university administrators are expected to put in place the necessary facilities and protocols for the implementation of the stipulated measures for the safety of the students and staff of the universities.

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