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Situation assessment and natural dynamics of COVID-19 pandemic in Nigeria, 31 May 2020



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ABSTRACT

Background: The coronavirus disease (COVID-19) remains a global public health issue due to its high transmission and case fatality rate. There is apprehension on how to curb the spread and mitigate the socio-economic impacts of the pandemic, but timely and reliable daily confirmed cases' estimates are pertinent to the pandemic's containment. This study therefore conducted a situation assessment and applied simple predictive models to explore COVID-19 progression in Nigeria as at 31 May 2020.

Methods: Data used for this study were extracted from the websites of the European Centre for Disease Control (World Bank data) and Nigeria Centre for Disease Control. Besides descriptive statistics, four predictive models were fitted to investigate the pandemic natural dynamics.

Results: The case fatality rate of COVID-19 was 2.8%. A higher number of confirmed cases of COVID-19 was reported daily after the relaxation of lockdown than before and during lockdown. Of the 36 states in Nigeria, including the Federal Capital Territory, 35 have been affected with COVID-19. Most active cases were in Lagos ($n = 4064$; 59.2%), followed by Kano ($n = 669$; 9.2%). The percentage of COVID-19 recovery in Nigeria (29.5%) was lower compared to South Africa (50.3%), but higher compared to Kenya (24.1%). The cubic polynomial model had the best fit. The projected value for COVID-19 cumulative cases for 30 June 2020 in Nigeria was 27,993 (95% C.I: 27,001–28,986).

Conclusion: The daily confirmed cases of COVID-19 are increasing in Nigeria. Increasing testing capacity for the disease may further reveal more confirmed cases. As observed in this study, the cubic polynomial model currently offers a better prediction of the future COVID-19 cases in Nigeria.

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Abbreviations

SARS-CoV-2	severe acute respiratory syndrome coronavirus 2
CC	cumulative cases
WHO	world health organization
NCDC	Nigeria centre for disease and control
ECDC	European centre for disease prevention and control
RSE	root square error
FCT	Federal capital territory
CFR	case fatality rate

Introduction

The novel severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) infection causing COVID-19 disease was first confirmed on the 27 February 2020 in Lagos state, Nigeria and by 31 May 2020, there were 10,162 confirmed cases [1,2]. COVID-19 disease constitutes a threat to public health; therefore, timely and reliable monitoring of cases are necessary for proactive response, containment and control. Additionally, effective response activities to mitigate the spread of COVID-19 in Nigeria will benefit greatly from accurate assessment and prediction of COVID-19 cases in days ahead. This will enhance the preparedness of governments at various level in terms of effective management and deployment of testing facilities, health workers, and essential drugs to alleviate the disease spread.

Studies [3–8] have used mathematical and statistical models to describe observed patterns of infectious diseases, monitor and examine their trend, dynamics and geographical spread. These models vary from simple [3,9] to complex [10–12] and were identified as effective approaches to understanding the spread of an epidemic. However, complex models require various epidemiological data for the estimation of their parameters; hence, much time would be needed to build such models [13]. Besides, such data do not either exist or readily available in Nigeria. Early assessment and prediction of COVID-19 cases and knowledge of when the disease will be at its peak in the course of the pandemic are pertinent to public health response preparedness. Knowledge of when the COVID-19 curve would be flattened is the top priority for policymakers in Nigeria. Although a few studies have been conducted in the area of infectious disease modelling in Nigeria [14–16], a methodological exploration using simple mathematical model to predict COVID-19 cases is yet to be developed. Mathematical modelling of the dynamics of COVID-19 can have a direct influence on the optimal allocation of limited resources [17].

The trajectory of COVID-19 confirmed cases and its associated morbidity and mortality in advanced countries (USA, Italy, Spain and United Kingdom) [2,18] left policymakers in Nigeria with concerns about how to effectively handle its spread. We, therefore, provided a situation assessment of COVID-19 as at 31 May 2020 and analysed its cumulative cases using four simple mathematical models: linear, quadratic, cubic, and exponential. This is with the view to providing policymakers with information that can give quick insight into the future dynamics of the COVID-19 pandemic in Nigeria.

2. Methods

2.1. Study setting and population

This study was conducted in Nigeria. The country has the largest population (over 200 million) in Africa [19]. After the COVID-19 index case was reported, many measures have been introduced to curb the spread and contain the disease in Nigeria [20]. These include, lockdown in some of its 36 states and Federal Capital Territory (FCT), closure of international airports and its many international land borders, social distancing, wearing of facemasks, hand washing and use of hand sanitizers. The Nigeria Federal Government plans to rapidly scale diagnostic testing to cover all the 36 states including the FCT, but as at the time of writing this report, only 63,882 tests have been conducted [1]. Besides Nigeria, seven other Africa (Gabon, Ghana, Ivory Coast, Kenya, Mali, Senegal and South Africa) and seven non-Africa (Bangladesh, Germany, India, Iran, Italy, Pakistan, USA) countries were purposively selected. These countries were selected because they experienced the outbreak of COVID-19 almost concurrently as Nigeria and the magnitude of the cumulative confirmed cases was relatively comparable to that of Nigeria on the World COVID-19 table as at the time of data extraction for this study.

2.2. Data collection and analysis

The data for this study were collated from the websites of the European Centre for Disease and Control (ECDC – a World Bank data source) and Nigeria Centre for Disease Control (NCDC) [1,18]. In our analysis, the final epidemic size was the COVID-19 cumulative case as at 31 May 2020.

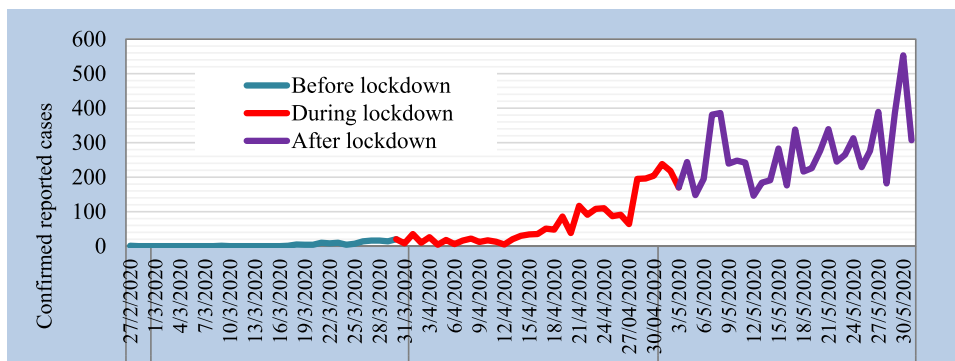


Fig. 1. Daily COVID-19 confirmed cases in Nigeria, as at 31 May 2020.

The linear, exponential, quadratic (order two polynomial) and cubic (order three polynomial) growth models were employed to fit the daily COVID-19 confirmed cases in Nigeria. These models have been used for curve fitting for similar infectious diseases in the recent past [3] and are briefly described below.

Linear model: The linear model describes a response variable ($N_i(t)$) in terms of a linear combination of time as the main explanatory variable.

$$N_i(t) = a_0 + a_1t_i + \epsilon_i.$$

where a_0 and a_1 are respectively intercept and slope, which are estimated by the least square estimation, t is the time-point, and ϵ_i are mutually uncorrelated random errors with mean (0) and common variance (σ^2).

Exponential model: The exponential regression is used when modelling an outbreak of a disease that exhibits slow growth at the beginning but speeds up rapidly without limit and then slows down until no new case of the disease is found. The model is of the form:

$$N_i(t) = Aexp(rt) + \epsilon_i$$

where A is the intercept, r is the intrinsic rate of natural increase (i.e., population growth rate with no environmental resistance) and t and ϵ are as defined above.

The assumptions of continuous reproduction, identical organisms and constant environment over time and space are required. However, the exponential model is robust and provides reasonable precision even if these assumptions are not met.

Polynomial model: A polynomial equation is of the form;

$$N_i(t) = a_0t^0 + a_1t^1 + \dots + a_{m-1}t^{m-1} + a_mt^m + \epsilon_i.$$

where m is the polynomial order and $a_0, a_1, a_2, \dots, a_m$ are constants.

The main assumption is that growth rate can either be on increase or decrease with time. This assumption supports the suitability of polynomial equation for modelling COVID-19. The early growth patterns of some disease outbreaks has been investigated in a previous study using polynomial model [3]. Meanwhile, Adjusted R-square values are reported for model fit comparison; the values indicate the amount of variation explained by the model. The model with the highest value was adjudged as being the most adequate. Studies have used Adjusted R-square (coefficient of determination) as a regression diagnostic tool for model performance [3].

3. Results

3.1. Situation assessment

3.1.1. Trend of the daily COVID-19 confirmed cases in Nigeria

The first and the second cases of COVID-19 were confirmed on 27 February and 9 March 2020, respectively. The chart shows an increasing trend with a consistent increase of confirmed cases from 1,932 on 30 April 2020 to 10,162 on 31 May 2020. There was an increase in the daily confirmed cases of COVID-19 during this period with the highest number of cases (389) found on 27 May 2020. Although an increasing daily COVID-19 confirmed cases were reported during the lockdown, a higher number was found daily after the lockdown was relaxed (Fig. 1).

3.1.2. Geographical spread of COVID-19 in Nigeria

Out of the total of 36 states, 35 including the FCT have been affected with COVID-19 with Lagos state ($n = 4945$; 48.7%) as the epicentre. Other states mostly affected by the disease were Kano (954, 9.4%), FCT ($n = 660$; 6.5%), and Katsina ($n = 364$; 3.6%) (Fig. 2).

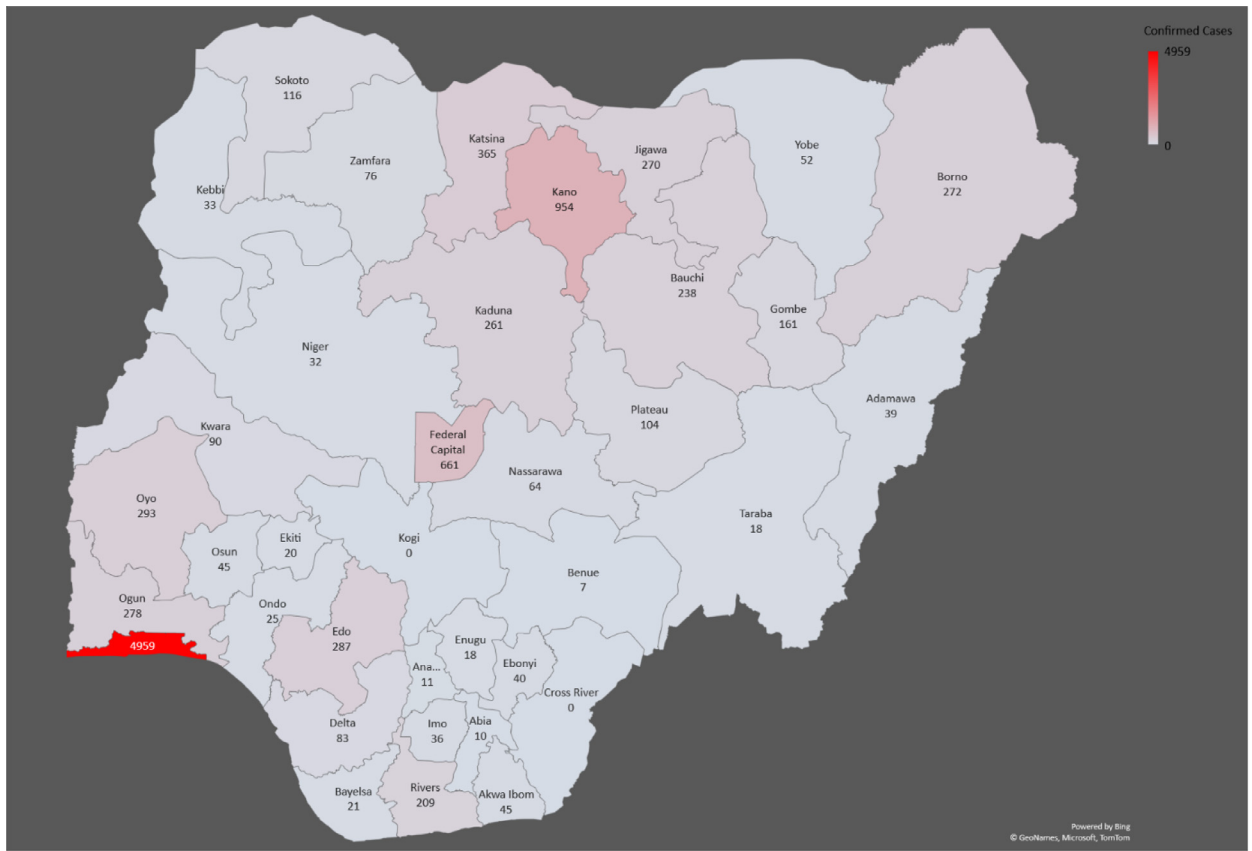


Fig. 2. Distribution of total confirmed cases of COVID-19, as at 31 May 2020.

3.1.3. COVID-19 positive tests in Nigeria and elsewhere

The percentage of positive COVID-19 tests is a function of the country's designed protocol for testing and it can be a measure of appropriateness of the test. The percentage of COVID-19 positive cases in Nigeria (16.6%) was comparable to the percentages observed in countries like Iran (16.2%), Bangladesh (15.4%), Pakistan (12.9%), and Gabon (18.8%). However, it was higher than the proportion of positive cases in USA (10.2%), Italy (6.0%), India (5.2%), Germany (4.6%), Ivory Coast (10.7%), Ghana (3.7%) and Kenya (2.5%). So far, 63,882 COVID-19 tests had been conducted in Nigeria (Fig. 3).

3.1.4. Distribution of COVID-19 recovery cases and case fatality rate (CFR) in Nigeria and some countries

About one-third ($n = 3122$; 29.5%) of COVID-19 cases recovered. This percentage was lower than 49.7% found in South Africa, but higher compared to Kenya (24.1%). Countries in other world regions like Germany (90.3%), Iran (78.3%) and Italy (67.9%) had higher recovery rates; USA (21.4%) and Bangladesh (21.4%) had lower recovery rates compared to Nigeria. The CFR of COVID-19 was 2.8% in Nigeria (Fig. 4).

3.2. Simple growth models of COVID-19 in Nigeria

Of the four models used in this study, the cubic model provided a better fit for the daily confirmed cases of COVID-19 while the exponential model over-estimated it. The linear model clearly deviated from the COVID-19 data trajectory (Fig. 5).

The Adjusted R-square affirms that the cubic model fits the confirmed COVID-19 cases better than quadratic, linear and exponential models (Table 1). The projected value of COVID-19 confirmed cases for 30 June 2020 in Nigeria was 20,274 (95% C.I: 19,211 – 21,337) and 27,993 (95% C.I: 27,001 – 28,986) using quadratic and cubic models respectively (Fig. 6).

4. Discussion

COVID-19 has become a huge global challenge, with a sporadic increase in daily confirmed cases and deaths. This propelled the WHO to declare the COVID-19 outbreak a pandemic and called for a multi-sectoral approach to contain it [21]. However, the knowledge gap on the expected cases of COVID-19 ahead of the current period is crucial owing to its anticipated short and long term effects on individuals, society, economies and so on [22]. The projection of cases will inform plans and policies required for containment and prevention of the spread of COVID-19 disease.

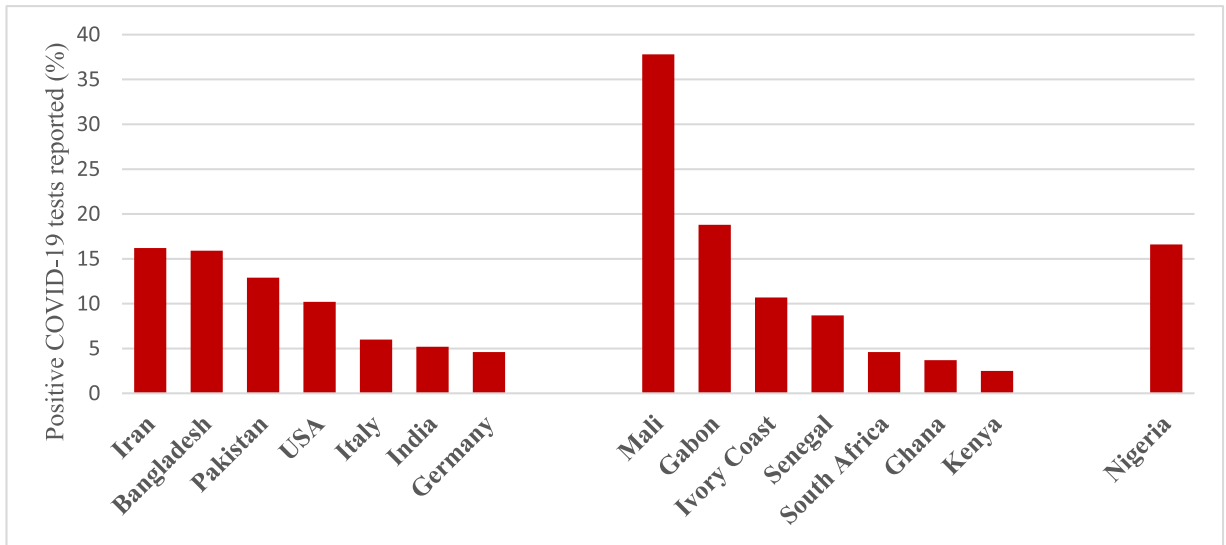


Fig. 3. Percentage of total positive COVID-19 tests reported in Nigeria and selected countries.

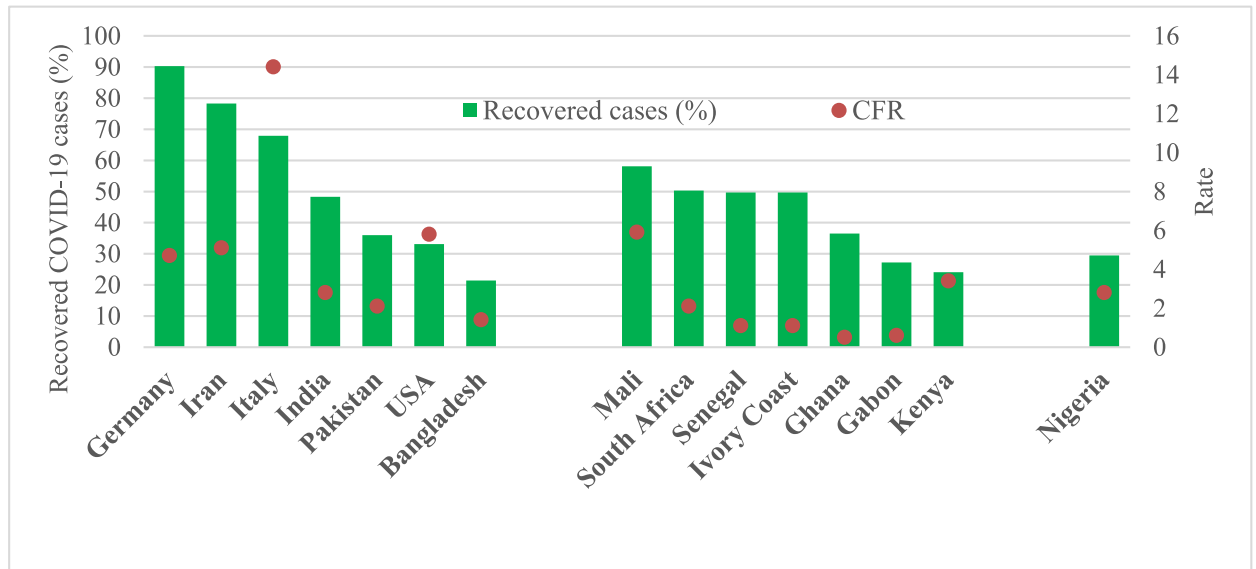


Fig. 4. Percentage of recovered COVID-19 confirmed cases and case fatality rate (CFR) in Nigeria and elsewhere.

The current study is, in part, a response to the WHO call and to the Nigeria Government’s determination to explore every possible approach to contain the pandemic [20]. We used simple mathematical models to examine the dynamics and progression of COVID-19 in Nigeria. The outcome of this study will aid contingency plan and improve knowledge on the expected COVID-19 cases in the days ahead. This we hope will enhance preparedness, and drive policy and other efforts geared towards the containment of the disease.

We found a sharp increase in the daily confirmed cases in Nigeria compared with what the situation was at the beginning of the outbreak. This pattern is expected perhaps due to the lackadaisical attitudes of the people towards compliance with COVID-19 preventive measures and protocols in Nigeria [1]. The study further shows that as at 31 May 2020, about one of every three infected cases in Nigeria has recovered. The recovery rate in Nigeria is comparable to the observed rates in fellow African countries like Ghana, Gabon and Kenya but lower than the observed rate found in South Africa and in some other nations outside Africa.

The cubic polynomial model appears to have predicted the future confirmed cases better than linear, quadratic and exponential models. Perhaps attributable to the current testing arrangement for COVID-19 in Nigeria that is still low compared to some countries in sub-Saharan Africa, the exponential model appears to over-estimate the expected cases. Inadequate community testing and untested asymptomatic individuals in the population can explain the reason for this finding. We

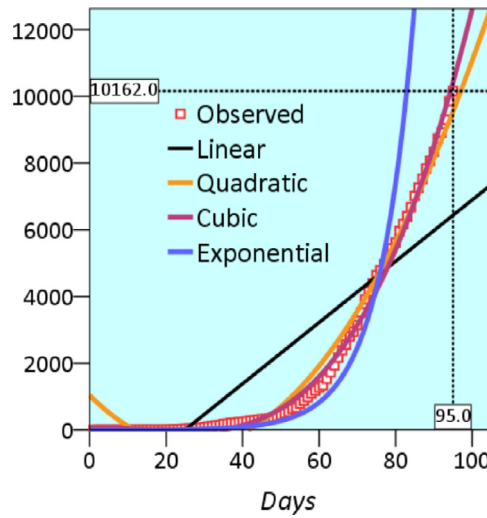


Fig. 5. COVID-19 observed and fitted cumulative cases - as at 31 May 2020.

Table 1
Model summary and parameter estimates.

Equation	Model summary			Parameter estimates			
	R ²	F statistic	p-value	a ₀	a ₁	a ₂	a ₃
Linear	0.739	263.717	<0.001	-2285.367	91.800		
Quadratic	0.981	2395.847	<0.001	1037.680	-113.750	2.141	
Cubic	0.996	7262.623	<0.001	37.971	8.037	-1.014	0.022
Exponential	0.937	1374.508	<0.001	1.147	0.110		

R² – Adjusted R-square (coefficient of determination).

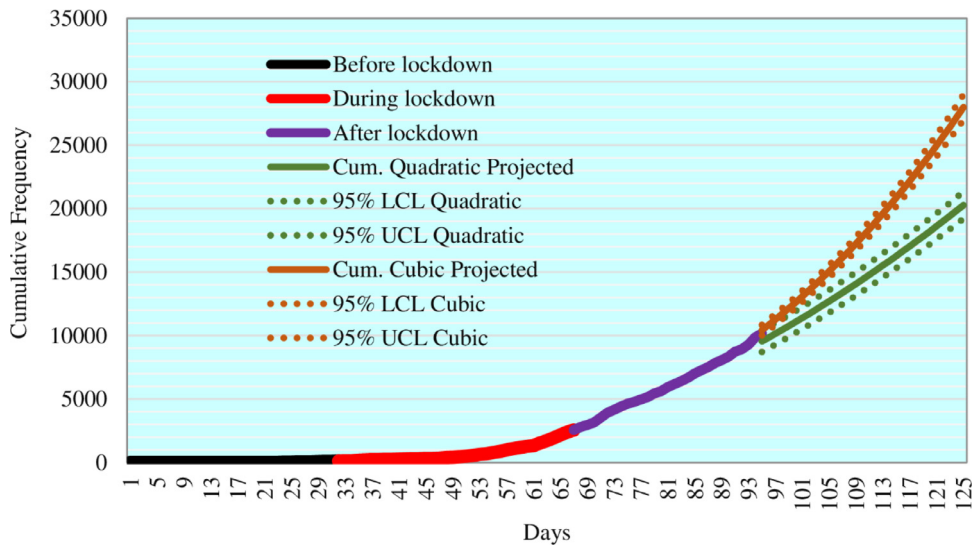


Fig. 6. Observed and projected cumulative cases of COVID-19, as at 31 May 2020.

projected that by 30 June 2020 the expected confirmed cases in Nigeria would be 27,993 provided the current criteria for testing, modes of testing, compliance of COVID-19 containment mechanisms (which include partial lock-down, hand washing, use-of-hand-sanitiser, wearing-of-face-mask, social distancing) remain the same. It is likely that the cumulative confirmed cases of COVID-19 may shoot up sporadically in Nigeria if the current trend is sustained. Nonetheless, there could be other internal and external factors that may influence this trend. As Nigeria and other African countries begin to witness a massive upsurge in the COVID-19 confirmed cases, there is a need to understand the expected trend in the next few weeks. Unlike in the early days of the virus, the current trend in number of daily confirmed cases of COVID-19 in Nigeria is alarm-

ing. The tide changed when Lagos state adopted more proactive ways of COVID-19 testing which include a house-to-house testing of the traced contacts and establishment of testing centres across all its local government areas in the middle of April 2020 [1].

The poor rate of testing in Nigeria may be responsible for the low confirmed cases in the earlier days of the pandemic. Of Nigeria's confirmed 10,162 cases between 27 February 2020 when the index case was reported [20] and 31 May 2020 across 35 of the 36 states in Nigeria including the FCT, only 63,882 tests have been conducted in Nigeria as at 31 May 2020 [1]. In this study, Lagos state had the highest share of both confirmed and active cases as at 31 May April 2020. These reported higher number of COVID-19 cases and active cases found in Lagos State are expected due to its large population size and density. The porous land borders and sea activities also make the state more vulnerable to the disease than any other state in Nigeria [23]. Conversely, the projected increase in number of cases in Nigeria should be a source of concern for neighbouring countries that shares borders with Nigeria. Cross-border transmission may also increase as people find a means of overcoming travel and movement restrictions. Port health agencies in these neighbouring countries such as Benin, Niger and Cameroon need to strengthen surveillance activities and prevention measures in border communities. Of course, it is not unlikely that the largest number of confirmed cases of COVID-19 in Lagos was responsible for its many active cases. With Nigeria's current population of over 200 million, the testing rate is below 400 per one million people [1]. An implication that a lot needs to be done in terms of increasing the COVID-19 testing capacity in Nigeria.

The outcomes of this study are limited by the available parameters to model the COVID-19 data in Nigeria. Currently, the only data available for public use in Nigeria is restricted to the daily confirmed cases, recovered individuals and deaths. Important variables like characteristics of those tested, recovery or death that should have driven some expositions of statistical modelling are not available. The data used for this study are subject to the scope of testing practised in different countries. The wider the testing, the higher the likelihood of reported cases. Besides, differential in availability of testing kits, surveillance and contact tracing and consequent testing, the sensitivity and specificity of COVID-19 testing algorithm could affect the accuracy and comparability of our estimates among countries.

5. Conclusions

The spread of COVID-19 is on the increase in Nigeria. COVID-19 cases have been found in 35 out of 36 states in Nigeria including the FCT. The percentage of cases who have recovered is encouraging compared to some other African countries, but the COVID-19 tests conducted remains low. A change in testing coverage and approach particularly, capacity for community testing will reveal more confirmed cases in Nigeria. The cubic polynomial model currently offers a better prediction of the future COVID-19 cases in Nigeria than any other models used in this study. We recommend broader testing across Nigeria.

Declaration of Competing Interest

The authors declare no competing interest.

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Authors' contributions

ASA, AAF, JOA, KOO, RFA and SOO conceptualised and designed the study. ASA and AAF analysed the data while ASA, AAF, JOA and RFA interpreted the analysed data. ASA, AAF and RFA drafted the original manuscript. ASA, AAF, JOA, KOO, EJA, RFA, SOO and SAA reviewed and edited the manuscript. All authors have read and agreed to the published version of the manuscript.

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