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Estimating the Exponential Growth and Mortality Rate of COVID-19 in Nigeria: A Data Driven Analysis

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***Abstract*— The novel coronavirus (COVID-19) disease outbreak which initially started around mid-December 2019 in Wuhan, China has spread to almost all countries of the world including Nigeria. There are very few studies on some of the basic epidemiological features: exponential growth (EG) and mortality (CFR) ratesof this outbreak in the country while in some cases there are no reliable estimates of these parameters region or state wise. In this study, a purely data-based statistical method was employed to estimate the EG and CFR of the COVID-19outbreak. Daily numbers of laboratory-confirmed COVID-19cases and deaths were collected from April 3 to May 15, 2020 for four regions: Lagos, Kano, Nigeria (except Lagos and Kano) and Nigeria. Simple linear regression model was applied to estimate the CFR while a curve estimation regression model was used for the EG for each region. By 15 May 2020, the estimated exponential growth (EG) rate ranged from 7.0% (95% CI: 6.9–7.8%) in Lagos through 9-0% (95% CI: 8.5–9.3%) in Nigeria and 10% (95% CI: 9.5–10.5%) in Nigeria (except Lagos and Kano) to 12.7%(95% CI: 11.6–13.7%) in kano with a doubling time ranging from 5.5 days in Kano through 6.9 days in Nigeria (except Lagos and Kano) and 7.7 days in Nigeria to 9.9 days in Lagos. The estimated CFR ranged from 1.3% (95% CI: 1.1–1.5%) in Lagos through 3.2% (95% CI: 3.1 – 3.3%) in Nigeria and 4.4% (95% CI: 4.2 – 4.5%) in Nigeria (except Lagos and Kano) to 4.5% (95% CI: 3.9 – 5.0%) in Kano. The study estimates suggest that Lagos is better managed than other regions. Kano has to improve on measures to slow the transmission and reduce mortality rate. Nigeria's overall situation is still manageable but efforts should be improved upon in curtailing transmission most especially in states where early detection is still low and clinical responses not effective.**

***Index Terms*— COVID-19, coronavirus,mortality rate, case fatality rate (CFR),exponential growth (EG) rate.**

I. INTRODUCTION

The novel coronavirus (COVID-19) disease outbreak was initially identified in mid-December 2019 in Wuhan, China [1], but was not reported to the World Health Organization (WHO) until 31 December, 2019 [2]. The disease has caused serious illness and death and the symptoms include fever, cough, shortness of breath and occasionally watery diarrhea [2]. The incubation period could be between 3–7 days, at most 14 days, which varies greatly among patients [1]. The disease is highly contagious and could be asymptomatically infectious, that is to be infectious during incubation period when no symptoms are shown on the patients [1].

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As of May 15, 2020, the disease has confirmed cases of over 4.3 million and close to 300, 000deaths worldwide, while in Nigeria, the disease has confirmed cases of 5,445, deathsof 171 and 1320recoveries [4]. It is presently in 35 states in Nigeria including the Federal Capital Territory (FCT).The index case in the country was reported on February 27, 2020[3] and the transmission dynamics; rate of infection, mortality etcetera which was slowly progressing in the first few weeks of the epidemic [5]now seems to be increasing exponentially most especially in states like Lagos and Kano which are currently the epicenters in southern and Northern part of the country respectively [3].

The characteristics of COVID-19 outbreak and control are distinct from existing infectious diseases [1].So to understand the basic epidemiological features of this outbreak and ensure proper control of the disease, require reliable estimates ofthe exponential growth (EG) rateand the mortality or case fatality rate (CFR) [2].The CFR describes the level of mortality (death cases and its progression) while the exponential growth rate describes the level of increase of infected cases over time.

Several studies have estimated some of these epidemiological characteristics of the early dynamics of COVID-19 for different countries and regions of the world where there was an outbreak,but much deserve to be done in Nigeria [5].Very fewstudies are available and in some cases none with respect to geo-political regions or state wise, most especially epicenters such as kano state in North-central region, Edo state in South-South region or Lagos in South-West region. Estimating these parameterson region or state basicswill undoubtedly be of great significance for clinicians, public health practitioners, government officials and other relevant stakeholderswithin those regions or states because the virus detection rates and the healthcare resources may differ in different regions and secondly for the purpose ofimplementing efficient and effective disease control interventions[2].

The study therefore sought to estimate the case fatality rate (CFR) and exponential growth (EG) rateof COVID-19in four regions of Nigeria: Lagos, Kano, Nigeria (except Lagos & Kano) and Nigeria.

II. METHODS

A. Sources of Data

In this study, the daily number of laboratory-confirmed COVID-19 cases and the daily number of COVID-19 deaths released by the Nigeria Centre for Disease Control (NCDC)

[3] from February29, 2020 to May15, 2020 was used to construct a real-time database. The study specifically used data between April 3, 2020 and May 15, 2020 (which ensured that all regions in the study had at least a single case mortality in order to avoid the influence on the CFR and EG estimation).

B.Statistical Model

A simple linear regression model was applied to estimate the CFR of the period observed in each region. We used daily cumulative number of laboratory-confirmed cases as predictor variable and cumulative deaths as outcome variable. The slope of the fitted line can be used as an estimate of the CFR, and the confidence interval of CFR observed from the regression analysis[2]. While in modeling the exponential growth curve, the real-time growth of COVID-19 for the observed period was estimated by fitting exponential curves to the daily confirmed cases and its changes in time, using the curve estimation regression model. This curves enabled the understanding of growth progression of the disease in the different regions and the doubling time was mathematically computed for each regionby using [6].

III. RESULTS

A. Figure (Nigeria epidemic data of COVID-19 outbreak)

Fig. 1 below shows the simple linear fitting results of COVID-19 pandemic for different regions: (A) Lagos, (B) Kano, (C) Nigeria (except Lagos and Kano) and (D) Nigeria. Within the period, under consideration, there was a total of 2278, 761, 2406 and 5445 confirmed cases in Lagos, Kano, Nigeria (except Lagos and Kano) and Nigeria respectively. Similarly, the number of deaths recorded for each region were 36, 33, 102 and 171 respectively.

The coefficient of determination, R-squared ranged from 0.872 to 0.995 which showed that the epidemic data of confirmed cases and death closely followed the linear trend. That is each regression line closely fits the observed data. Nigeria as a whole had the best of goodness of linear fitting with R-squared of 0.995 (*Figure 1D*) amongst the other regions. The linear fitting result for Lagos is not as effective as other regions, with R-squared of 0.8717 (*Figure 1A*).

The estimated CFR of COVID-19 in Kano state was the highest with 4.5% (95% CI: 3.9 – 5.0%) (*Figure 1B*), while Lagos had the lowest and best estimated CFR of 1.3% (95% CI: 1.1–1.5%). The other regions: Nigeria (except Lagos and Kano) and Nigeria had estimated CFR of 4.4% (95% CI: 4.2 – 4.5%) and 3.2% (95% CI: 3.1 – 3.3%) respectively.

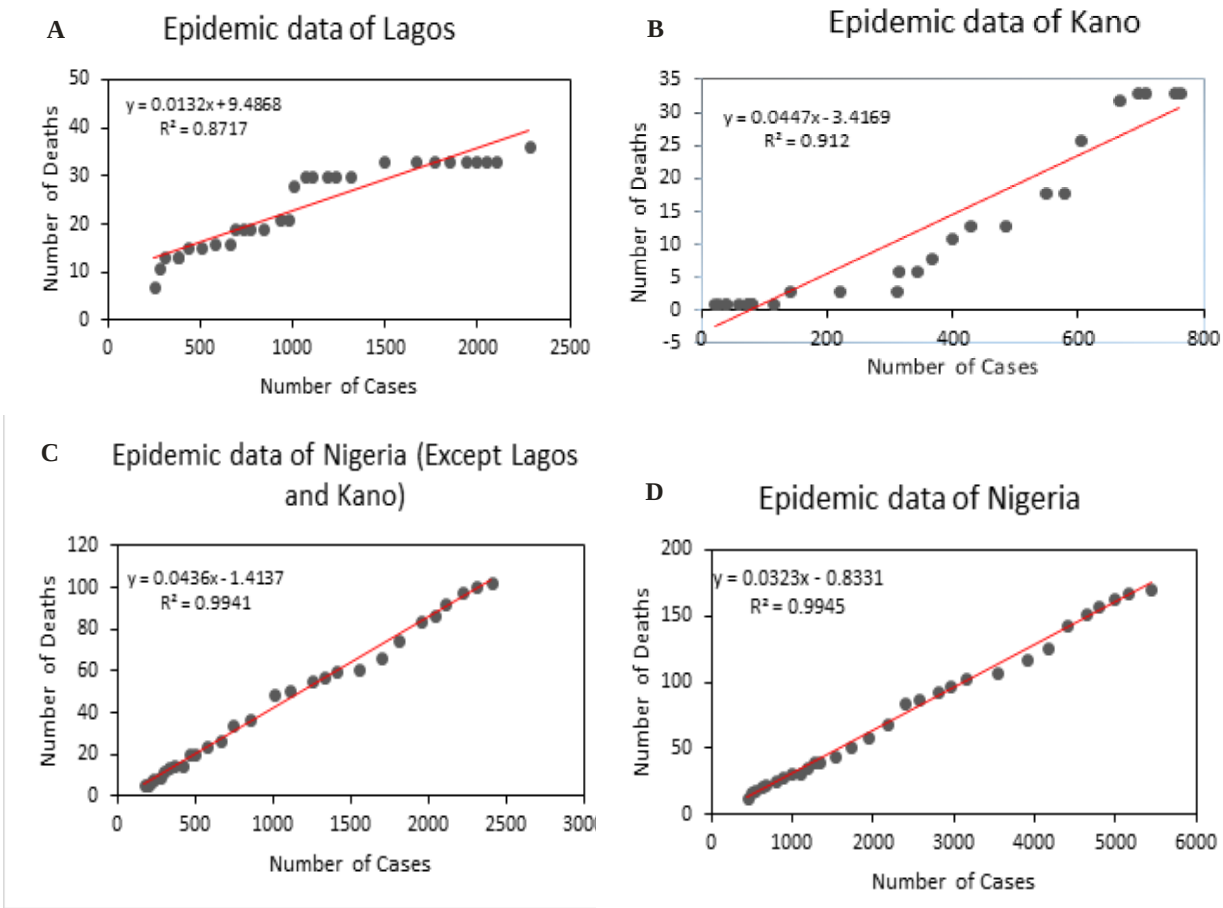

Fig. 1*: The simple linear model fitting of COVID-19 pandemic for different regions: (A) Lagos, (B)Kano, (C) Nigeria (except Lagos and Kano) and (D) Nigeria.*

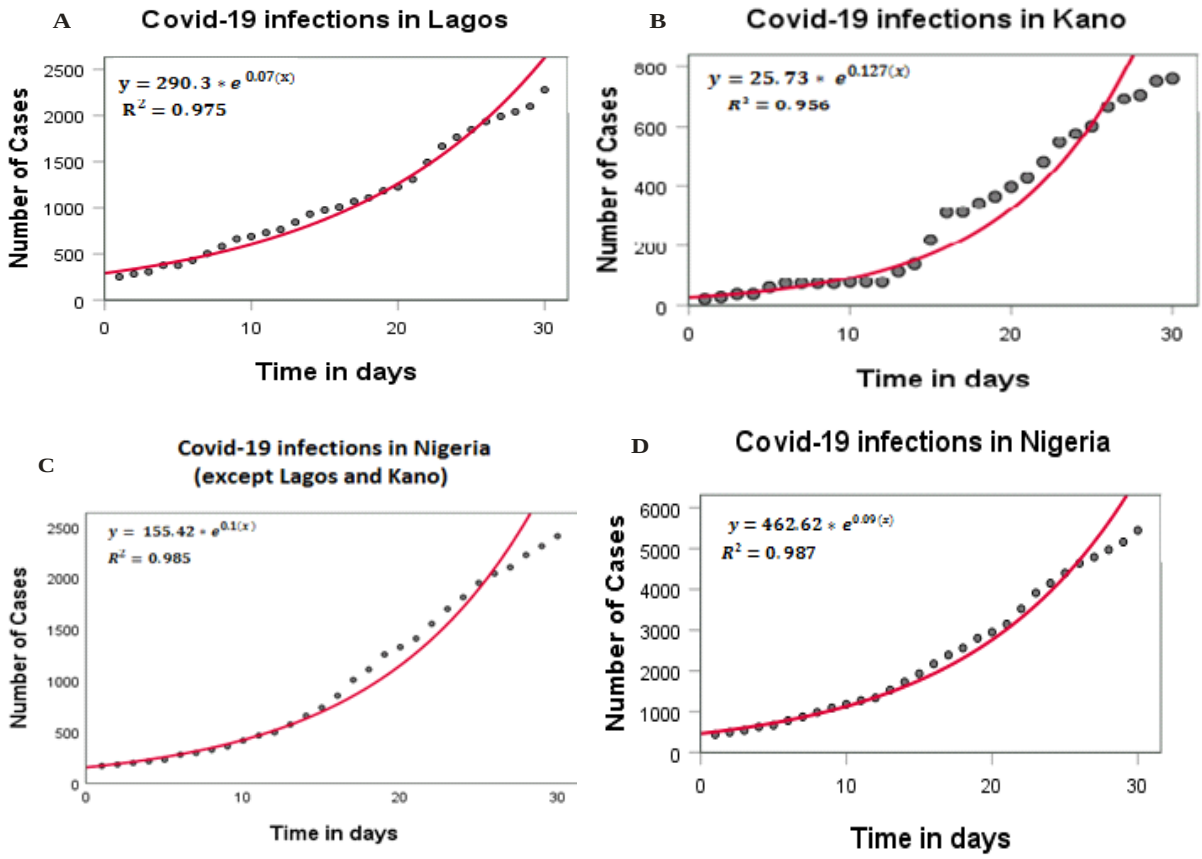

Fig. 2*:Epidemic curve of the confirmed cases of COVID-19 and the exponential growth fitting (EG) for different regions: (A) Lagos, (B)Kano, (C) Nigeria (except Lagos and Kano) and (D) Nigeria*

A. Figure (Infectionsof COVID-19 outbreak in Nigeria)

Fig. 2 below presents the epidemic curves and fitted exponential growth (EG). An EG model was fitted separately to the observed epidemic data for the four regions. The estimated exponential growth rate of COVID-19 in these regions ranged from 7% to 12.7%. Kano had the highest exponential growth rate with an overall rate of 12.7% (95% CI: 11.6–13.7%) (*Figure 2B*). While Lagos was the lowest and best with an exponential growth rate of 7%, (95% CI: 6.9–7.8%). The two other regions; Nigeria (except Lagos and Kano) and Nigeria had 10% (95% CI: 9.5–10.5%) and 9% (95% CI: 8.5–9.3%) respectively (*Figures 2C & 2D*).

The doubling time of the epidemic for the four regions was computed and it also ranged from 5.5 to 9.9 days. Kano had the least doubling time of 5.5 days (95% CI: 5.1–6.0) while Lagos had the highest doubling time of 9.9 days (95% CI: 8.9–10.0) which actually is the best amongst the compared regions. Other regions were Nigeria (except Lagos and Kano) with doubling time of 6.9 days (95% CI: 6.6–7.3) and Nigeria doubling time of 7.7 days (95% CI: 7.5–8.2).

IV. DISCUSSION

As of May 15, 2020, the disease is presently in 35 states in Nigeria including the Federal Capital Territory (FCT) and seems to be growing exponentially. The early days of the disease was slowly progressive but the transmission dynamics has changed presently. Initially most of the cases were directly or indirectly connected to imported cases so transmission was slow unlike now where transmission has entered the community case and more cases are being detected [4].

Lagos, the economy hub of the nation had shown an estimated growth rate of 7%, (95% CI: 6.9–7.8%). the lowest and the best amongst the compared regions. Lagos had the highest and best doubling time of 9.9 days (95% CI: 8.9–10.0).An estimated growth rate of 7%, (95% CI: 6.9–7.8%).implies a daily increase of cases by 7%. While the estimated doubling time of 9.9 days (95% CI: 8.9–10.0). shows that in every 9.9 days the cases are likely to double. Fair as it may seem, but the daily new cases are still surging high. That is, the rate of transmission may be slow when compared to other regions, but the new cases per day still increases[4]. The lockdown,isolation and hospitalization measures by the state government so far have been commendable but the effort can be improved upon.

The CFR of Lagosat 1.3% (95% CI: 1.1–1.5%), the lowest amongst the regions is quite impressive. Based on the study's estimate of the confidence interval, the CFR in Lagos will likely not go above 1.5%, even in the near future if the detection methods, healthcare resources, clinical treatment, and other factors are stable or even improved upon.

Kano state, the commercial nerve centre of Northern Nigeria, had her index case on April 11, 2020 and recorded first mortality on April 16, 2020 [4]. The growth was gradual until almost3 weeks of her index case when it began to increase. This may be due to low detection as a result of inadequate testing facilities [7-8]. Shortly after then, growth began to increase and according to the exponential growth fitting, Kano had an estimated growth rate of 12.7% (95% CI: 11.6–13.7%), the highest amongst the compared regionsand a least doubling time of 5.5 days (95% CI: 5.1–6.0). By this estimated growth rate of 12.7% (95% CI: 11.6–13.7%), it implies a daily increase of cases by 12.7%. While the estimated doubling time of 5.5 days (95% CI:

5.1–6.0) shows that in every 5.5 days the cases are likely to double. The estimated growth rate and doubling time of Kano are quiteworrisome when compared to other regions. This calls for more attention. More effective measures;more isolation centres and stricter lockdown measures could be imposed to reduce rate of transmission.

Also from the simple linear fitting, Kanoshowed a CFR of 4.5% (95% CI: 3.9 – 5.0%), the highest amongst others. At the initial stage, within the early weeks the CFR was relatively stable but picked up with a steady increase from around the third week. From the trend on the model the CFR has to be well monitored because the tendency to increase is obvious. More healthcare resources and effective clinical treatment could be implemented.

The region of Nigeria (except Lagos & Kano) has an estimated growth rate of 10% (95% CI: 9.5–10.5%) with a doubling time of 6.9 days (95% CI: 6.6–7.3) The EG rate and doubling timeis second highest and it will require more commitment from state governments and other stakeholders in ensuring compliance to the measures: lockdown, isolation, hospitalization and others. Some state governments have really been proactive over these measures others seem to have been slow in their approach[9]. Some also ensured the distribution of palliative to encourage citizens to obey the lockdown measures since a good number of Nigerians live on daily income. The region also has a CFR of 4.4% (95% CI: 4.2 – 4.5%) indicating that there will still be high pressure of epidemic prevention and control and clinical treatment.

Nigeria as a whole had an estimated growth rate of 9% (95% CI: 8.5–9.3%) with doubling time of 7.7 days (95% CI: 7.5–8.2).The country had a slow epidemic growth start after the index case on February 27, 2020 but gradually picked up and continued to rise despite some epidemic measures that were put in place. Some of these measures included:an international travel ban imposed on 15 countries considered to be high risks countries on 20 March 2020, followed by a total ban of all international flights in and out of the country; early closure of all schools, universities and worship centres throughout the country and restriction on movements within and outside major cities, whichwere all enforced starting 29 March 2020[5].

Perhaps imposing total international and local flights ban earlier enough, could have been helpfulbecause the gradual rise was directly and indirectly related to imported cases. As reported by [5]more than 47% of the earlier cases were imported cases (travel-related).Inter-state restriction was another measure that would have been introduced earlier as it would have prevented local importation from state to state [10]. Other reasons for the rise could be attributed to the seemingly ineffective lockdown measure because a good proportion of the Nigerian are daily income earners [11] and the supposed palliative to cushion the effect of the lockdown were not effectively distributed in some states [12-13].

Another area that needs attention is local dissemination of COVID-19 information to the locals where majority still believe the pandemic is not trueand as such will not observe those NCDC protocols: physical distancing, continuous hand washing, nose masking etcetera[14]. This lack of proper awareness and in some cases, fear of stigmatization could hinder people with suspected cases from coming forward for testing or even treatment when infected.Looking at the overall assessment, the situation is still manageable and within control. So all hands must be on deck to turn around the tide of the pandemic in the country.

The study's estimate of CFR for Nigeria which is 3.2% (95% CI: 3.1 – 3.3%) is consistent with the tentative estimate of 3% for CFR as daily reported by NCDC and WHO [4;15]. This rate can be improved upon by ensuring early detection, improved health care facilities and effective clinical responses.

The growth rate and CFR of the same disease vary greatly in different countries or even different regions of the same country, and will be affected by numerous factors such as health control policies, medical standards, and detection efficiency. This study employed a purely data-driven statistical approach to estimate the exponential growth (EG) rate and mortality rate (CFR) of the COVID-19 outbreak. The real-time growth of COVID-19 for the observed period was estimated by fitting exponential curves to the daily confirmed cases and its changes in time, using the curve estimation regression model. While a simple linear model similar to the model of [2] used for china was used for the CFR. The CFR model fitting efficiency is high and the estimation of confidence interval is accurate for the observed period of the outbreak.

Be that as it may, the study cannot be exempted from limitations. Firstly, the accuracy of the data analyzed is subject to the official figures released by the NCDC, which could be prone to errors at any point. For instance, April 8, 2020 posted 8 cases for Bauchi state as against 6 cases, but was latter corrected on April 9, 2020 on the basis of retesting suspected cases (NCDC, 2020). Secondlythe study being a statistical analysis of the data for an observed period of COVID-19, has limited ability to predict what the CFR or EG will finally be. These variables are subject to many factors including time. But the estimates are reliable enough to guide for successful control on the COVID-19 in these regions.

V. CONCLUSIONS

In this study, the COVID-19 estimates of exponential growth (EG) rate ranged from 7.0% (95% CI: 6.9–7.8%) through 9-0% (95% CI: 8.5–9.3%) and 10% (95% CI: 9.5–10.5%) to 12.7%(95% CI: 11.6–13.7%) with a doubling time ranging from 5.5 days through 6.9 days and 7.7 days to 9.9 days. The estimated CFR ranged from 1.3% (95% CI: 1.1–1.5%) through 3.2% (95% CI: 3.1 – 3.3%) and 4.4% (95% CI: 4.2 – 4.5%) to 4.5% (95% CI: 3.9 – 5.0%). These estimates are relatively manageable at least when compared to similar figures in other places around the world[16]. The regions of Lagos and Nigeria as a whole are commendable but the efforts can still be improved upon most especially controlling the daily count. Kano and Nigeria (except Lagos & kano) have more work to be done. The mortality level has to be reduced and daily count controlled. This means effective lockdown measures, early detection, better isolation and heath care facilities and effective clinical responses. So far the NCDC efforts are commendable.

Government at all levels must work assiduously to improve the overall health care management in the country, both in provision of facilities and relevant human resources. Giving of palliatives to encourage stay at home order should be properly managed. Strategy economic stimulus both now and post COVID-19 should be properly conceived to help the citizens mostly private sectors get back on their feet.

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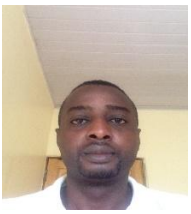

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