Estimation of exponential growth rate and basic reproduction number of the coronavirus disease 2019 (COVID-19) in Africa

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Abstract

Since the first case of coronavirus disease 2019 (COVID-19) was detected on February 14, 2020, the cumulative confirmations reached 834 including 17 deaths by March 19, 2020. We analyzed the initial phase of the epidemic of COVID-19 in Africa between 1 March and 19 March 2020, by using the simple exponential growth model. We estimated the exponential growth rate as 0.22 per day (95%CI: 0.20 – 0.24), and the basic reproduction number R_0 to be 2.37 (95%CI: 2.22-2.51) based on the assumption that the exponential growth starting from 1 March, 2020. Our estimates should be useful in preparedness planning.
Keywords: COVID-19; reproduction number; pandemic; statistical modelling.

Introduction

Since the end of 2019, an outbreak of coronavirus disease 2019 (COVID-19), now a pandemic (2020 (World Health Organization, 2020b; Gilbert, 2020), caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) (World Health Organization, 2020a) has hit China severely, in particular, the epicenter, Wuhan, the capital city of Hubei province. The city has been locked down since January 23, 2020 and the lockdown is expected to be lifted on April 8, 2020. As of the March 23, the epicenter has moved to Europe and Middle East, after the outbreak was largely controlled in China. Many countries are facing a rapid increasing trend of confirmed cases. The case-fatality-rate varies wildly from country to country. As of 24 March 2020, more than 400,000 people have been infected with COVID-19 with over 18,000 death globally (out of which about 90% of the death cases were from Italy, Spain and China) (World Health Organization, 2020a; World Health Organization, 2020c).

Africa reported its first case of COVID-19 in Egypt on 14 February 2020 (Gilbert, 2020 World Health Organization, 2020c). As of 24 March 2020, Africa has more than 2300 confirmed cases with 32 death cases (World Health Organization, 2020c). The African region has been described as one of the most vulnerable with the COVID-19 infection (Gilbert, 2020) in the initial phase, due to the fact that Africa is important commercial partner of China and as a result, large volume of business person travel to the region. Since the epicenter is now in Europe, due to the close tie between Africa and European countries, African countries face even bigger threat.

Several control measures have currently been taken by most of the African countries to prevent/reduce the spread of COVID-19, especially against case importation from the COVID-19 epicenters. Some of the measures includes travel ban to and from the most COVID-19 hit countries, school closures, temporary ban of religious gathering and so on (Gilbert, 2020; World Health Organization, 2020d; Nigeria Center for Disease Control, 2020). Nevertheless, the ability to curtail or reduce and control the local transmission after case importation depends largely with how African government are seriously sustaining the current recommended measures. Due to the fragile health care system, insufficient health workers, lack of water, and sanitizers for maintaining hygiene in the region. African countries need to find their optimal strategies to stop the spread of COVID-19 in its region.

Numerous epidemiological studies have been conducted to understand the transmission dynamics of COVID-19, which is quantified in two key parameters, the basic reproduction number (the expected number of secondary cases that may be caused by a typical primary case during his/her infectious period in a wholly susceptible population, R_0) and the serial interval (time delay between the symptom onset of a primary case and his/her secondary case, SI). High reproductive number and short serial interval imply rapid growth. In the initial phase, the epidemic (number of new cases over time) typically exhibited exponential growth. The basic reproduction number is a function of the exponential growth rate (r) and the serial interval. Studies on the basic reproduction number, exponential growth rate and serial interval (Zhao et al., 2020a; Zhuang et al., 2020; Ma, 2020, Nishiura et al., 2020; Du et al, 2020; and Zhao et al., 2020b), many of which have shown an R_0 of about 2.0 – 5.0 and initial under-reporting/under-detection during the early phases of the outbreak in China.

The aim of this study is to estimate the exponential growth rate, thus the basic reproduction number (with previously estimated serial interval in other regions) of the COVID-19 pandemic in Africa at the early stage, which should be valuable in informing the official and public in the preparedness against COVID-19 spread, forecasting the trend, and highlighting the importance of sustaining strict measures in order to curtail the spread.

Methods

We obtained the daily number of COVID-19 cases time series data in Africa from World Health Organization (WHO) from 1 March to 19 March, 2020 (https://www.who.int/emergencies/diseases/novel-coronavirus-2019/situation-reports/). Although there were 3 confirmed cases throughout Africa from 14 February to 29 February 2020, we did not include them as there were no additional case reported until 1 March, 2020. In this work, we considered the situation from 1 March 2020 as the number of cases and death started a steady increasing trend.

Referring to recent modeling studies (Zhao et al., 2020a; Ma, 2020), we model the epidemic curve by employing the exponential growth proposed by Ma et al. (Ma, 2020). The Poisson likelihood framework is adopted for data fitting and parameter estimation. The intrinsic growth rate (γ) was estimated, and the basic reproduction number R_o computed via $R_o = 1/G(-\gamma)$ with 100% susceptibility for COVID-19 presumed (Wallinga, 2007). The function $G(\cdot)$ represents the Laplace transform, which is the moment generating function of the probability distribution for the serial interval (SI) of the disease (Zhao et al., 2020a; Ma, 2020). Since the transmission chain of COVID-19 in Africa is yet to be fully uncovered, we adopted the SI estimated in Zhao et al. (Zhao et al., 2020c). We modelled the distribution of COVID-19 SI as Gamma distributions with a mean of 4.7 days and standard deviation (SD) of 2.9 days obtained by Zhao et al. (Zhao et al., 2020b).

Results and discussion

As of 19 March, 2020, a total of 834 infected cases were reported, with 17 fatal cases, giving an overall case fatality rate (CFR) of 2.04% throughout Africa, among them only 3 cases with no death reported in February 2020. The exponential growth fitting results are depicted in Figure 1. The fitting results matched the observed daily number of cases, which implies that the early outbreak data in Africa were largely following the exponential growth at an estimated rate 0.22 per day (95%CI: 0.20 – 0.24), which is slightly larger than previous estimates (Zhao et al, 2020a; Nishiura et al 2020; Li et al 202). We estimated the basic reproduction number R_o to be 2.37 (95%CI: 2.22-2.51), which is also depending on the estimates of the SI during the early epidemics. Our basic reproduction numb R_o estimates is significantly larger than 1 and broadly consistent with recent studies (Zhao et al., 2020a; World Health Organization, 2020e).

We suggested that the current COVID-19 outbreaks in Africa could increase rapidly if the measures were not strictly sustaining, which includes temporary bans of international travels, religious gathering, avoid social distancing and so on. Our analysis and estimation of R_0 rely on the accuracy of the SI of COVID-19 estimated previously based on cases from Hong Kong by Zhao et al. (Zhao et al., 2020b).

We reported that the mean $R_0$of COVID-19 in Africa is likely to be 2.37 which could vary from 2.22 to 2.51 and is consistent with the previous estimates, (World Health Organization, 2020e, Zhao et al., 2020a; Imai et al., 2020; Read et al., 2020). With an R_o at 2.37, the theoretical infection attack rate will be as large as 87%, namely 87% of Africa will be infected. However, we need to point out that the classical final size overestimated the infection attack rate in the influenza pandemic 1918 and influenza pandemic 2009. These two influenza pandemics had R_o around 2 and 1.5, respectively. The observed infection attack rate was round 20% in England and Wales and 10% in Hong Kong in the first year. Theoretically, the infection attack rates are 80% and 58%, respectively. The case-fatality-rate of 1918 was around 2%, thus the situation of panic and governmental action was similar to COVID-19 pandemic. While the case-fatality-rate of 2009 pandemic was so low thus there was virtually no large-scale control. Thus, the expected infection attack rate in a year could reach the same scale as 1918 pandemic, namely 25%, in the worst scenario, which is indeed terrible situation. We need to be prepared and strict action needs to be taken.

Conclusion

We estimated the exponential growth rate as 0.22 per day (95%CI: 0.20 – 0.24). We estimated that the mean R_0 of COVID-19 in Africa to be 2.37 (95%CI: 2.22-2.51), if we assume a relatively constant testing effort through the period.

Declarations

Ethics approval and consent to participate

The data were collected from public domain, and thus neither ethical approval nor individual consent was not applicable.

Availability of materials

All data used in this work are publicly available.

Consent for publication

Not applicable.

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Disclaimer

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Conflict of Interests

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Authors' Contributions

SS, SZ and DH conceived the study, carried out the analysis, and drafted the first manuscript. All authors discussed the results, critically read and revised the manuscript, and gave final approval for publication.

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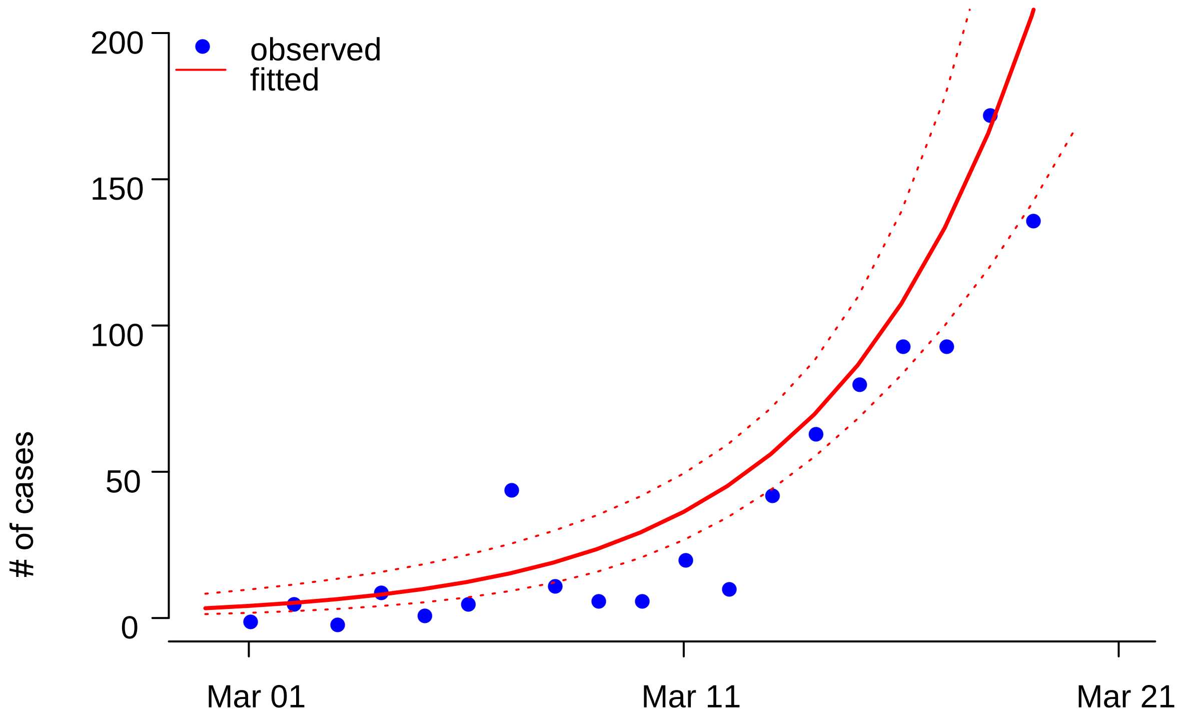

Figure 1. The observed (dots) and fitted (curves) daily number of COVID-19 cases time series in the Africa. The blue dots are observations, and the curves are fitting results. The red bold curve represents the mean fitting result, and the red dashed curves are the 95% confidence intervals.