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Trends of COVID-19 in the Central Africa Sub-region: Effective Health Care, Effect of Endogenous Parameters or a Matter of Time?

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

Background: After the worldwide spread of the coronavirus pandemic, several experts predicted a health catastrophe in Africa. However, the expected earthquake ultimately did not occur and the statistics of the number COVID-19 cases and deaths for other continents (Europe, America, Asia) were far higher than those of Africa. This study focused on Central Africa tried to explain this low incidence of COVID-19.
Methodology: A cross-sectional time series method was adopted and the data of COVID-19 cases and deaths for Angola, Cameroon, Chad, Central African Republic, Congo Brazzaville, Democratic Republic of Congo, Gabon, Equatorial Guinea and Sao Tome and Principe between March and

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November 2020 were extracted from the World Health Organization COVID-19 database. The evolution of COVID-19 cases and deaths for each country were plotted and the accuracy measures such as Mean Absolute Percentage Error, Median Absolute Deviation and Mean Squared Displacement were calculated. Association between the countries and the prevalence of cases, deaths and recovered was visualized through principal component analysis.

Results: The results showed that the highest number of cases was observed in Cameroon (21,793) while Sao Tome and Principe scored the smallest one (962). However, based on the total population, the prevalence of COVID-19 cases was high in Sao Tome and Principe (0.436%) and Gabon (0.400%). The highest death percentages (≥2%) were observed in Chad (6.742%), RDC (2.708%) and Angola (2.592%) while the highest recovered percentages were in Gabon (99.10%), Equatorial Guinea (97.62%) and Cameroon (97.02%). Development of traditional medicines and modification of food behavior including consumption of plant extracts appear as the reasons for the highest recovered rates. The accuracy measurements showed that the trend curves were not correlated with the actual evolution of the pandemic, but the Spearman correlation test revealed that except Equatorial Guinea (r=0.042, p=0.817), the evolution of COVID-19 cases and deaths were strongly correlated.

Conclusion: The overall prevalence and incidence of COVID-19 is low in the countries of the Central Africa sub-region despite the problems facing the health systems of these countries.

Keywords: COVID-19; Central Africa sub-region; positive cases; death cases; prevalence; healthcare system.

1. INTRODUCTION

The current outbreak of COVID-19 (SARS-CoV-2; previously 2019-nCoV), which started in Hubei province in the People's Republic of China, has spread to all the continents and almost all countries. On January 30th, 2020, the WHO Emergency Committee declared a global health emergency based on increasing rates of case notification in countries that were already affected [1]. Given the proven dangerousness of SARS-CoV-2, several states have set up various protocols to limit its spread among the population by closing borders or limiting flights, strict lockdown, social distancing, individual protection measures (wearing masks and gloves) since a specific treatment or vaccine were still unavailable [2-4]. Despite all these measures, the situation remained complex and after the exit from lockdown which was observed between February and August 2020 in most countries around the world, several countries saw the number of confirmed cases starts to rise again but with fewer deaths than at the beginning of the pandemic [5].

The WHO and most researchers around the world predicted the worst for African countries. However, the latter seems to have been and appears to be very weakly affected [6]. Indeed, on November 4th, 2020, there was 644,730 deaths in America with 20,862,392 positive cases; 289,753 deaths in Europe with 11,531,650 positive cases; 146,171 deaths in South-East Asia, with 9,408,048 positive cases; 80,882 deaths in Eastern Mediterranean with 3,177,903 positive cases meanwhile in Africa only 30,064 deaths were recorded with 1,331,971 positive cases Africa [7]. In addition, it is noted that the most affected countries are those which are supposed to have the most efficient and sophisticated health care, and therefore the most able to manage a public health issue of such magnitude [8,9]. Several hypotheses have been discussed to explain the low incidence of COVID-19 in African countries. Some authors have suggested that it is possible that the cases are underreported [10]. Indeed, the possibility of underreported cases of COVID-19 is not likely restricted to African countries; the outcomes of data-driven modelling analysis in China showed a high likelihood that cases of infection were unreported [10]. However, other researchers have tried to explain this low incidence of COVID-19 by the capacity of African countries to cope with a pandemic of this magnitude due to recurrent medication for malaria and the multiple sanitary crises that the continent has had to face, and this notwithstanding the supposed low quality of healthcare [11], lack of equipment, poor governance, and poorly trained staff [9,12]. In November 2020, while some countries, like France, fearing an imminent second wave, set up another lockdown of their population, the trends of the pandemic seem to be the same with a low incidence in African countries in general. The present study aims to study this phenomenon of low incidence of COVID-19 in Africa by using data provided by the WHO database on the evolution of the pandemic. Although data on some countries that have shown the highest incidences up to November 3, 2020 were investigated, the countries selected for the study were those of the Central Africa sub-region such as Angola, Cameroon, Gabon, Equatorial Guinea, Central African Republic (RCA), Democratic Republic of Congo (RDC), Congo Brazzaville, Sao Tome and Principe and Chad.

2. MATERIALS AND METHODS

2.1 Study Area and Period

The areas included in this study were the countries of the Central Africa sub-region. These countries were Angola, Cameroon, Gabon, Equatorial Guinea, RCA, RDC, Congo Brazzaville, Sao Tome and Principe and Chad. Fig. 1 presents the geographic localization of the Central Africa sub-region. The chosen period for this study was from the beginning of the COVID-19 pandemic in the different countries (March 2020) to November 2020.

2.2 Data Collection

The data used in this study were collected from the World Health Organization COVID-19 database. Data relating to the evolution of COVID-19 in the Central Africa sub-region were collected weekly from the detection of the first positive case in the country until November 3, 2020. For Cameroon, RDC and Sao Tome and Principe, data collection started during the week of March 2, 2020 while it started during the week of March 9, 2020 for Angola, Gabon, Equatorial Guinea, RCA, Congo Brazzaville and Chad.

Fig. 1. Geographical localization of the Central Africa sub-region

Light green=countries of the Central Africa sub-region which are not included in the CEMAC (Economic Community of Central African States) zone. Dark green=countries of the Central Africa sub-region belonging to the CEMAC zone

2.3 Method and Data Analysis

This study adopted a cross-sectional time series method and was carried out according to the method described by Bankole et al. [6] with some modifications. Briefly, after entering the weekly data of confirmed cases and deaths on Excel software, trend equations were plotted and accuracy measures such as Mean absolute percentage error (MAPE), Median absolute deviation (MAD) and Mean squared displacement (MSD) were obtained using Minitab version 18.1 (Minitab Inc., LLC, Pennsylvania, USA). The MAPE value expresses accuracy as a percent error. As such, the MAPE value indicates the percentage error of the linear regression and a high MAPE indicates a poor match between the real trend of deaths or cases and the linear regression while a low MAPE indicates a good match [13]. In addition, MAD expresses accuracy in the same units as the data (number of cases, number of deaths, weeks) which helps to conceptualize the magnitude of the error [13]. Indeed, the lower are the MAD values, the better is the adjustment. The MSD on the other hand measures the accuracy of the fitted values of the series, just as with the MAPE and the MAD, the lower are the values of MSD, the better is the fit [13].

Subsequently, the updated number of populations by country was recorded thanks to Worldometer [14] and the percentages of contaminations were calculated by dividing the total number of cases by the total population of each country. Then, the percentages of deaths and recoveries were calculated by dividing respectively the number of deaths and the number of recoveries by the number of total cases. Finally, a principal component analysis was carried out using the statistical software XLSTAT 2014 (Addinsof Inc., New York, USA) in order to visualize the correlations of the parameters mentioned above between the different countries of the Central African sub-region.

3. RESULTS AND DISCUSSION

3.1 Evolution of the Number of COVID-19 Cases and Deaths in Each Country of the Central Africa Sub-region

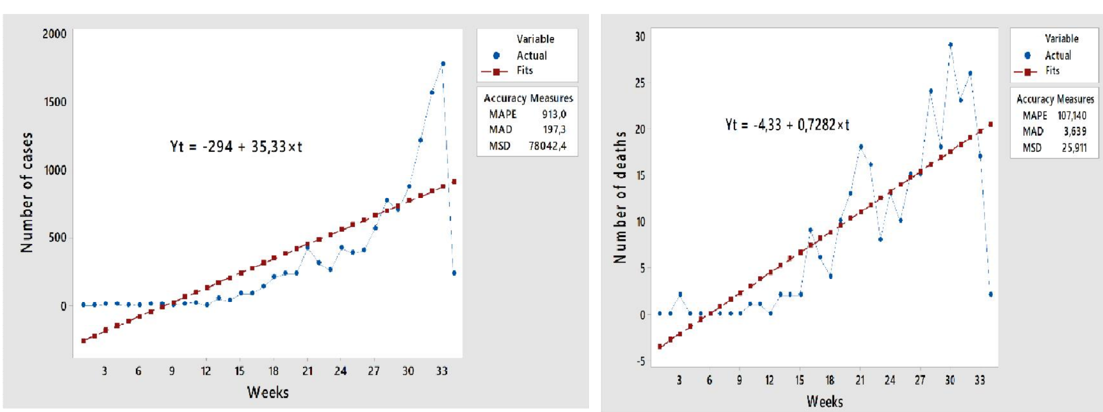
The trends of the number of cases and deaths of COVID-19 pandemic in Angola, Cameroon, Chad, Central African Republic (RCA), Congo Brazzaville, Democratic Republic of Congo (RDC), Gabon, Equatorial Guinea and Sao Tome and Principe are respectively represented in Figs. 2-10.

3.2 Evolution of the Number of COVID-19 Cases and Deaths in Angola

The trend in the numbers of COVID-19 cases and deaths in Angola is shown on Figs. 2 A and B, respectively. Fig. 2A shows that the number of cases was globally increasing during the first 34 weeks and a decrease in new cases recorded was observed from the 35th week compared to previous weeks. During the first 13 weeks, the number of new cases recorded remained relatively low (≤50) but increased rapidly from the 15th week (87) to reach its optimum at the 33rd week (1779 cases). During this same period, several European countries renowned for their sophisticated health care system, their acute knowledge and their modern and sophisticated means in medicine, were going through the most difficult periods of this global health crisis due to COVID-19 with the numbers of cases and deaths 20 to 30 times higher [15]. Ahmed [12] established that the world regions affected by malaria (including Angola) scored fewer or no cases of COVID-19 compared to countries where malaria is not rife and therefore where antimalarials are not regularly taken. The linear regression of the trend of COVID-19 cases confirmed the previous observations made in Angola and showed a growing trend in the number of cases. However, the accuracy check parameters (Table 1) such as MAPE (913.0), MAD (197.3) and MSD (78042.4) showed that this regression curve did not significantly ($p>0.05$) represents the evolution of the number of cases. Moreover, the trend in the number of deaths of COVID-19 in Angola (Fig. 2B) showed that the cumulative number of cases remained relatively low (2 deaths) until the 9th week after the registration of the first case. From the 16th week, the number of deaths increased quickly until reaching its peaks in the 28th (24 deaths), 30th (29 deaths) and 32nd (26 deaths) weeks. As for the number of cases of COVID-19 in Angola, the regression curve confirmed the growing trend but unlike the regression curve relating to the trend in the number of cases recorded in Angola, the value of MAPE (107.1) was not excessively high and the values of MAD (3.6) and MSD (25.9) were relatively low and revealed a slightly more significant fit. A deep analysis of trends in COVID-19 cases (Fig. 2A) and trends in COVID-19 deaths (Fig. 2B) showed that these two curves display almost similar behaviors. This observation was confirmed by the Spearman correlation test which showed a close correlation (r=0.954, p≤0.001) between the number of cases and the number of deaths due to COVID-19 in Angola (Table 1).

3.3 Evolution of the Number of COVID-19 Cases and Deaths in Cameroon

After the registration of the first case of COVID-19 in Cameroon, the number of positive cases detected increased rapidly, on the one hand, due to the spread of the virus (SARS-CoV-2) and on the other hand due to the choice made by the Ministry of Public Health to carry out systematic tests to detect as many cases as possible in order to limit the spread of the virus. Fig. 3A shows the evolution of the number of positive cases of COVID-19 recorded in Cameroon between March and November 2020. This Fig. 3A shows a sudden increase in the number of cases between the 3^{rd} (20 cases) and the 17^{th} week (1954 cases) with the highest number of cases in the 14^{th} (1895) and 16^{th} (1895 cases) weeks. Very strangely, while the weekly number of new cases recorded remained well over one thousand (1000) between the 12^{th} and the 20^{th} week, no case (0 cases) was recorded in the 18^{th} week. This observation could lead to lean in favor of the hypothesis of Melinda Gates who suggested that the low number of cases in Africa was due to an underreported and that this underreports itself was due to the lack of test kits [16]. However, other elements related to communication, logistics and the very strong centralization [17] of crisis management could also explain this strange observation. Furthermore, a monotonic decrease in the number of cases was observed from the 20^{th} week (Fig. 3A). This could be explained by the collective awareness of Cameroonians in the necessity to respect barriers and communication measures around the pandemic. Indeed, after the first case of COVID-19 confirmed in Cameroon in March 2020 by the Ministry of Public Health, the Government in its response plan against the pandemic, took thirteen measures to face it: ban on gatherings of more than fifty people; systematic closure from 6 p.m. of drinking establishments, restaurants and other places of leisure; limitation of urban and interurban travel to cases of extreme necessity; abstention from overloading in public transport by the drivers of bus, taxis and mototaxis; strict observance of hygiene measures recommended by the WHO [18]. The evolution of the number of deaths linked to COVID-19 in Cameroon is shown in Fig. 3B. This curve does not show any particular trend but had various peaks. However, an increase in the number of deaths was noted from the 6^{th} week with peaks at the 10^{th} (46 deaths), 15^{th} (58 deaths) and 19^{th} (46 deaths) weeks. In addition, from the 21^{st} week until the 35^{th} week (end date of data collection for this study), the number of weekly deaths of COVID-19 pandemic remained relatively low (≤10). Furthermore, as shown in Table 1, whether for the regression curve of the trend in the number of COVID-19 cases or the number of deaths, the accuracy measurements (MAPE, MAP and MSD) show that there is no adequacy between the predictive values and the real evolution of the pandemic. Finally, Spearman's correlation test demonstrated that there was a close match between the evolution of the number of COVID-19 cases and the number of deaths due to this pandemic in Cameroon (r=0.744, p≤0.001).



A B

Fig. 2. Trends of COVID-19 positive cases (A) and deaths (B) in Angola from March to November 2020

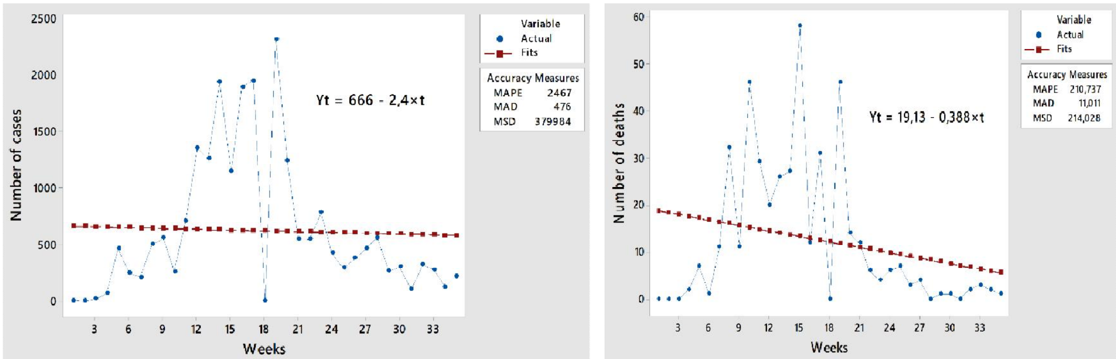


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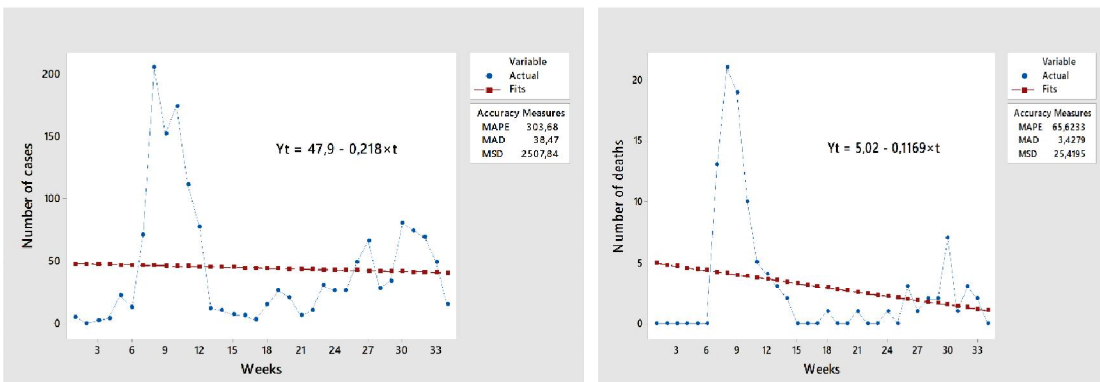
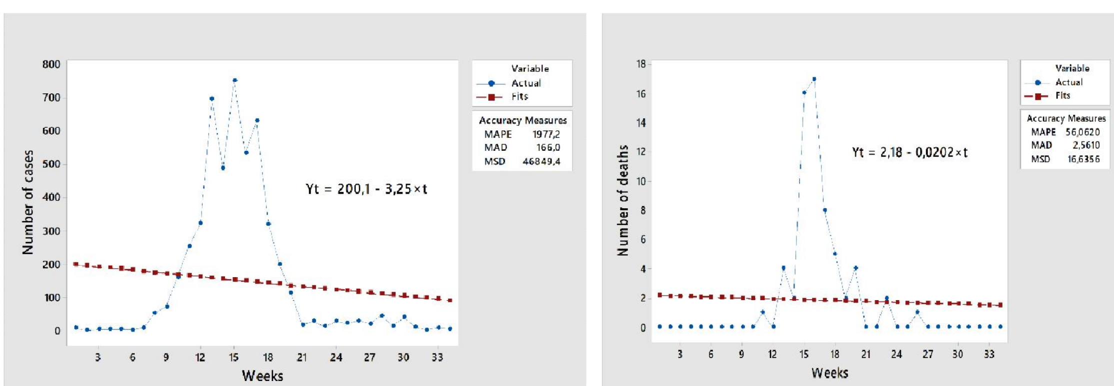
Fig. 3. Trends of COVID-19 positive cases (A) and deaths (B) in Cameroon from March to November 2020



A B

Fig. 4. Trends of COVID-19 positive cases (A) and deaths (B) in Chad from March to November 2020



A B

Fig. 5. Trends of COVID-19 positive cases (A) and deaths (B) in Central African Republic from March to November 2020

3.4 Evolution of the Number of COVID-19 Cases and Deaths in Chad

A meticulous observation of Figs. 4 A and B shows that COVID-19 cases and deaths evolve in a practically similar way. The number of new cases of COVID-19 weekly remained low (≤10) in Chad until the 4th week and the first deaths were recorded in the 7th week (13 deaths). Unlike Cameroon (highest number of cases in one week: 2324, 19th week) and Angola (highest number of cases in one week: 1779, 33rd week) the number of weekly cases in Chad has never exceeded 210 cases (the highest number of cases being 205, 8th week). To date, no real study has elucidated the reasons for this low prevalence of the COVID-19 in Chad, but as previously indicated, it has been reported that countries in Sub-Saharan Africa which regularly use antimalarials have a low prevalence than those who do not use them [12]. However, this hypothesis is not plausible in the current case due to the significant difference in the number of COVID-19 cases and the number of deaths between Chad and other countries such as Cameroon and Angola. It would be highly likely that it is a situation of underreporting cases because it's known that Chad (like most other countries in sub-Saharan Africa), is linked to poor indicators such as insufficient epidemiologic surveillance [19]; understaffed, fragmented, underfunded and poorly coordinated health system [20,21]; high poverty and mortality rate, heavy disease burden, and poorly developed infrastructure [22]. Notwithstanding the above, taking into account only the data on COVID-19 provided by the WHO database, it can be noticed in Fig. 4B that in Chad, with the exception of weeks 8 and 9 (19 and 21 number of deaths, respectively), the overall mortality rate is low and decreasing. However, the accuracy measurements (Table 1) show that the regression curves for the number of COVID-19 cases (Fig. 4A) and the number of deaths (Fig. 4B) do not match with the real evolution of the number of cases and deaths. Finally, similarly with Angola and Cameroon, there is a considerable correlation between the evolution of the number of COVID-19 cases and the number of deaths with a Spearman's Rho of 0.775 and a probability of p≤0.001 (Table 1).

3.5 Evolution of the Number of COVID-19 Cases and Deaths in Central African Republic

Between March and November 2020, the Central African Republic recorded 4,868 cases of COVID-19 and 62 deaths. Figs. 5A and 5B respectively show the evolution of the number of COVID-19 cases and the number of registered deaths. Overall, the 2 curves present the same trends, but the correlation between the evolution of the number of cases and the evolution of the number of deaths was found to be low (r=0.695) but highly significant (p≤0.001). The 3 major peaks of the recorded cases were observed at the 13th (696 cases), 15th (751 cases) and 17th (629 cases) weeks after the recording of the first case. At the same time, the 2 major peaks of deaths were observed in the 15th (16 deaths) and the 16th (17 deaths) weeks. The measurements of accuracy (Table 1) showed just as for the above-mentioned countries that the linear regression of the trend was not correlated with the real evolution of the pandemic. The low prevalence of COVID-19 in the Central African Republic gives rise to the same questioning as in the case of Chad and the other countries of Central Africa, given the almost similar situations of these countries in terms of infrastructure and health care system. Apart from the hypothesis of under-reporting of cases [16] and those of the regular use of antimalarials in these countries [12], Michael Ryan, director of emergency programs of the WHO suggested that the multiple crises and the history of African countries (including the Central African Republic) with epidemics have certainly played an important role in the management of COVID-19.

3.6 Evolution of the Number of COVID-19 Cases and Deaths in Congo Brazzaville

The number of positive COVID-19 cases in Congo Brazzaville increased slowly during the 15 first weeks following the venue of the pandemic (Fig. 6A). Exponential growth was noticed between the 15th and 18th weeks. During that period, the number of positive cases raised from 103 to 546. However, after the 18th week, it was observed a significant drop of contamination at a point that, 0 case was reached on the 24th week. This was the result of the strict lockdown established by the Government. Unfortunately, after that apparently good period a peak of positive cases (649) was observed in the 26th week. This observation could probably be due to a slackening of the barrier measure established by the World Health Organization. Then, the lockdown accompanied by curfew reinforced by the Government justify the significant decrease of contaminated cases after the 26th week as observed in Fig. 6A. From the 28th to the 34th

week, the contamination cases evolved in sawtooth. An explanation of that evolution could be the reduction of the number of people tested as time passed.

Death cases due to COVID-19 were reported in Congo Brazzaville during March to November 2020. As observed in Fig. 10 B, the number of deaths varies as time passed with peaks observed at the 4th, 10th, 14th, 16th, 21st, 23rd, and 27th week. The highest number of deaths were recorded at the 16th (13) and 23rd (18) week. It is important to highlight that a high number of positive cases associated with a high number of deaths was noticed in the 16th week. However, in the 23rd weeks where the number of positive cases was in net decrease, the highest number of deaths was recorded. This observation could be explained by the fact that, it takes approximately 2 weeks of incubation before the symptoms of COVID-19 appear [10,23]. Hence, complications leading to death might appear a few weeks later due to the lack of consumables and equipment required for the management of the COVD-19 such as medicine, respirators, scanners and oxygen [24]. Opposite to the curve showing the evolution of COVID-19 positive cases in Congo Brazzaville, the curve showing evolution of deaths was more fitted with linear regression as demonstrated by the MAD, MAPE and MSD values (Table 1). The possible association between the positive cases and deaths was assessed through spearman correlation. The results showed that the correlation was weak ($r=0.66$) but significant ($p<0.05$).

3.7 Evolution of the Number of COVID-19 Cases and Deaths in Democratic Republic of Congo

In Democratic Republic of Congo, the evolution of the number of positive cases appears as a Gauss curve (Fig. 7A). From week 1 to 7, although a slight increase of the number of cases is observed, it still remained low. After the 7th week, a significant increase was noticed until reach the highest number of cases at the 16th week (1018). This could be explained by the fact that the first tentative lockdown failed and was postponed. Also, the circulation of prejudices and false information about the COVID-19 in the country at the beginning of the disease could explain the increase of positive cases. A study conducted in Democratic Republic of Congo by Kuhangana et al. [25] from April 16 to 29 revealed 70% of participants do not have correct knowledge on COVID-19. Up to the 16th week, the number of cases globally decreases except the 20th, 22nd, 27th, 30th, 32nd and 34th weeks where a slight increase was noticed. This could result from the fact that the population relied on medicinal plants for which several researches claimed their potential anti-COVID-19 properties [26,27]. Besides, the application of hurdle measures recommended by the WHO could also explain the decrease of COVID-19 positive cases.

Concerning the evolution of the number of deaths due to COVID-19 in the Democratic Republic of Congo, Fig. 7B shows that number of deaths was high in several weeks. Peaks of deaths were noticed on weeks 4 (10 deaths), 10 (19 deaths), 14 (24 deaths), 16 (28 deaths), 17 (29 deaths), 21 (14 deaths), 23 (21 deaths), and 32 (26 deaths). As the number of positive cases increases, the number of deaths increases too, excepted the week 11 where a significant drop was noticed (2 deaths only). The highest number of deaths (29 deaths at the 17th week) was recorded one week after the peak of contamination (1018 cases at the16th week). This observation is comprehensible ($r=0.59$ and $p\leq0.001$) and could result from complications of the diseases (association with other non-communicable diseases such as diabetes, kidney deficiency, hypertension) as the number of contamination cases was in net progression from week 7 to week 16. A positive association between the increase of COVID-19 positive cases and the number of deaths was reported in several countries as highlighted by the World Health Organization [22]. However, after the 16th week, the number of positive decreased until the 34th week. An opposite behavior was noticed with the evolution of death. The most noticeable cases are observed in weeks 23 and 32. Globally, taking in consideration the MAPE, MAD and MSD values, the curve of positive cases showed a weak fitting to liner regression compared to the one of deaths. The important variation in the number of positive cases could justify the low fitting observed.

3.8 Evolution of the Number of COVID-19 Cases and Deaths in Gabon

Fig. 8A shows that Gabon faced three main peaks of contamination. The first one corresponding to the period between the 10th (659 cases) and the 12th (679 cases) weeks, the second one corresponding to the 15th week (965 cases) and the third one to the 20th week (863 cases). Between these peak periods, a significant increase and decrease in the number of positive cases were noticed. The first increase of the number of contaminations until reach maximum counts at the 10th and 12th week could be justified by the lags between the testing system and capacity as highlighted by UNICEF [28] in their report. The two weeks lockdown of Libreville metropolitan associated with the restriction of movement imposed by the Government could explain the decrease observed after that first contamination peak. After the lockdown period, the slackening of hurdle measures could be responsible for the highly increase of contamination as the highest contamination peak (965) cases was recorded. The mass testing strategy introduced by the Government could explain the significant decrease observed after the peak recorded in the 20th week.

The number of deaths increases the second week following the first reported case. From the 3rd to 6th week, no death case was signaled within the country. After the 6th week, an increase in the number of deaths was noted. The highest level of contamination was recorded at the 15th week (11 deaths). At that specific week, the country experienced the most important number of contamination (965 positive cases). Although the correlation between the number of cases and deaths was not strength (r=0.74) as expected, it was significant as shown by the p-value which was lower than 0.05. Up to the 15th week, the number of deaths has significantly dropped. A slight increase was noticed at the 20th week in response to the contamination peak observed the same week (863). This observation could be justified by the increase of the number of people tested as response measure of the Government (approximately 2000 tests per day from the beginning of July 2020).

3.9 Evolution of the Number of COVID-19 Cases and Deaths in Equatorial Guinea

The contamination in Equatorial Guinea was weak at the beginning of the crisis (Fig. 9A). The first peak was noticed at the 6th week (179 cases) and the second one at the 10th week (353 cases). After the second peak, the number of cases has fallen to 0 and stayed at that value from week 11 to week 17. Then two other peaks of contamination were noticed on the 18th (1307 cases) and 20th weeks (2471 cases). This observation could be explained by the fact that Government instructions were not widely respected by the population who were not aware of COVID-19 [29]. After the 20th week, the number of cases dropped significantly and stayed under 31 cases for the rest of weeks expected the week 23 where 105 cases were noticed. Emergency plans for prevention and contingency developed by the government in collaboration with the WHO and other partners as highlighted in the report of UNDP [29] could be responsible for the stagnation of the number of contamination cases after the 20th week.

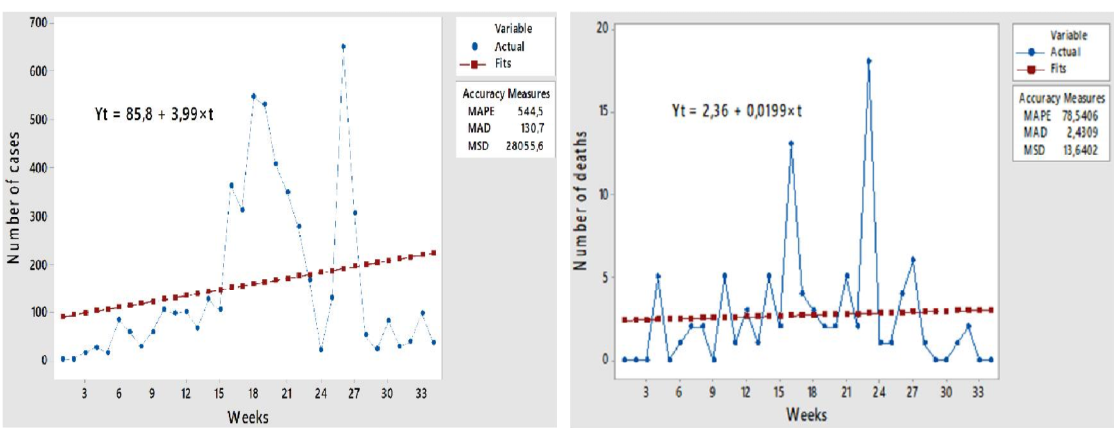


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Fig. 6. Trends of COVID-19 positive cases (A) and deaths (B) in Congo Brazzaville from March to November 2020

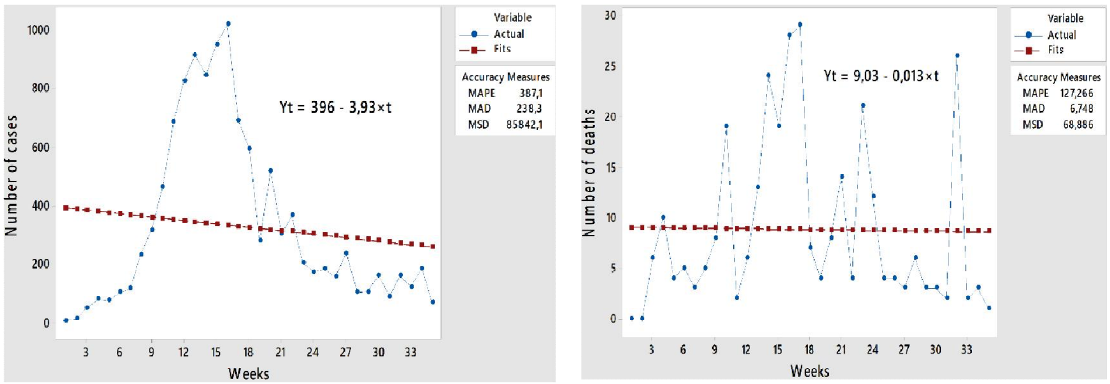

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Fig. 7. Trends of COVID-19 positive cases (A) and deaths (B) in Democratic Republic of Congo from March to November 2020

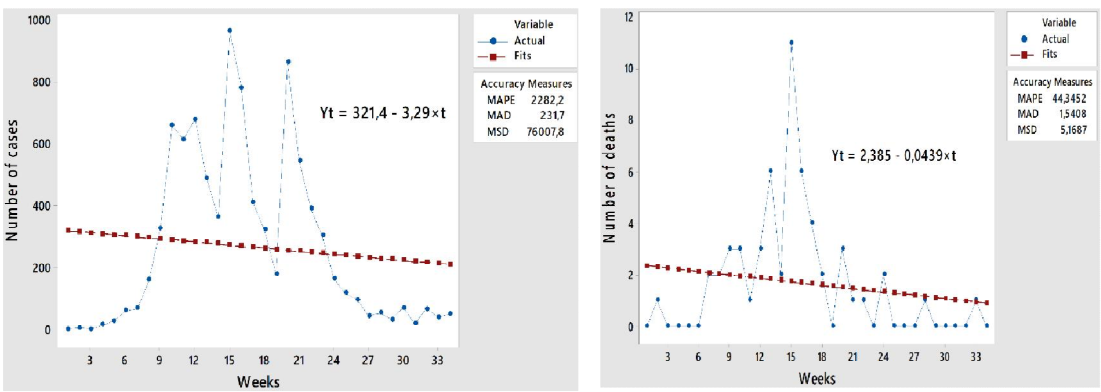

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Fig. 8. Trends of COVID-19 positive cases (A) and deaths (B) in Gabon from March to November 2020

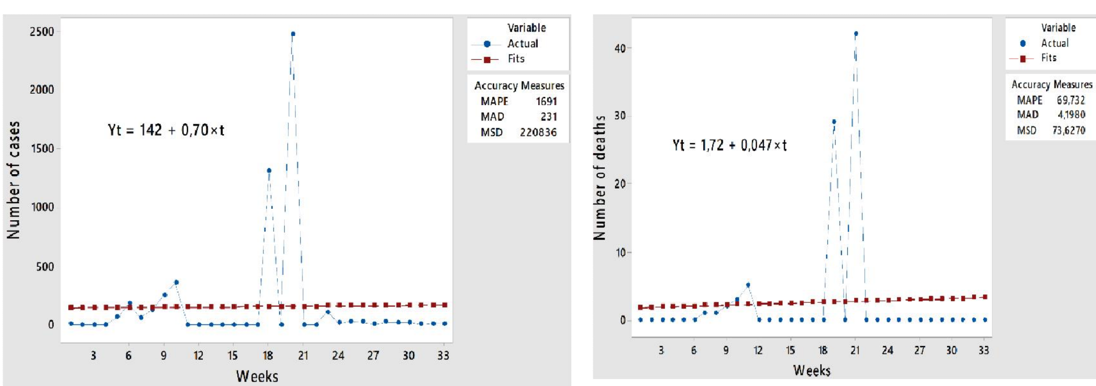

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Fig. 9. Trends of COVID-19 positive cases (A) and deaths (B) in Equatorial Guinea from March to November 2020

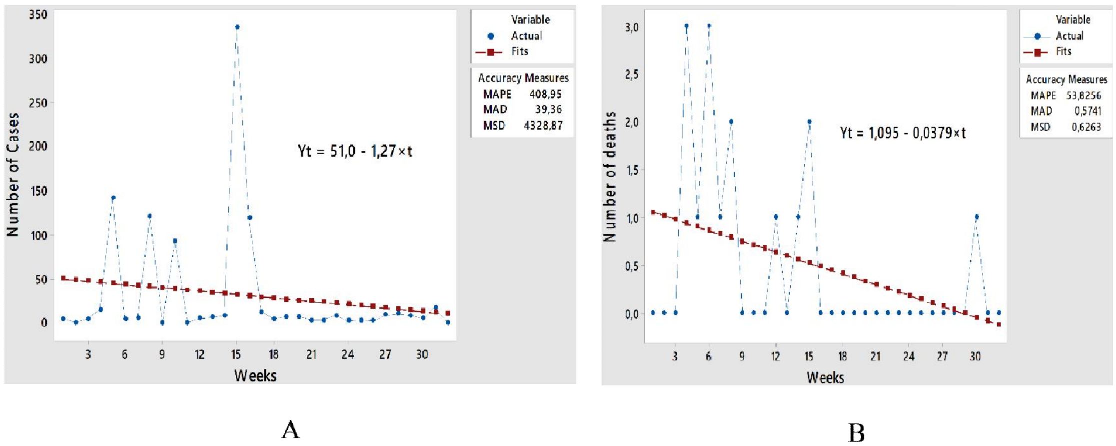

Fig. 10. Trends of COVID-19 positive cases (A) and deaths (B) in Sao Tome and Principe from March to November 2020

A deep analysis of Fig. 9B shows that the peak of death appeared one week after a peak of contamination. In fact, the first peak of death was observed at the week 11 (5 deaths) while at the week 10th a peak of contamination was noticed (353 cases). Similar observations can be noticed on one hand in the Fig. 9B at week 19 (29 deaths) and at week 21 (42 deaths), and on the other hand in the Fig. 9A at the week 18 (1307 cases) and at 20 (2471 cases). This result showed COVID-19 contamination in Equatorial Guinea lead to death despite the measures taking. An explanation to this observation could be the lack of consumables and equipment required for the management of the COVD-19 such as detection kits, medical mask, protection equipment for doctors, medicine, respirators, scanners and oxygen are also the leading causes of COVID-19 pandemic spreading [24]. However, a correlation analysis revealed a poor and non-significant correlation between the contamination cases and number of deaths (r=0.042, p=0.81).

3.10 Evolution of the Number of COVID-19 Cases and Deaths in Sao Tome and Principe

In Sao Tome and Principe, four peaks of COVID-19 contamination were observed on weeks 5 (142 cases), 8 (121 cases), 10 (93 cases) and 16 (336 cases). Generally, the number of positive cases was low compared to other countries. A significant increase of contamination cases was noticed and once the peak is reached, the number of positive cases drops significantly (Fig. 10A). Four weeks of low contamination precede the first peak, two weeks the second peak, one week the third peak and four weeks the fourth peak.

The death cases in Sao Tome and Principe were up to 3 (Fig. 10B). Very few cases of deaths (15 deaths) were noticed during the 35 weeks of investigation. Correlation between the number of deaths and the number of contamination cases was weak (r=0.37) but significant ($p<0.05$). The mitigation measures introduced by the Government such as closing school, bars, events…even in the absence of confirmed cases of COVID-19 might explain the low number of contamination and death recorded by the country [30].

3.11 Comparison of the Percentage of Cases, the Number of Recovered and the Number of Deaths between the Countries of the Sub-region

Using data provided by the WHO database on the evolution of the spread of COVID-19, the number of cases, deaths and recovered were recorded. The percentage of cases was calculated referring to the total population and the percentage of deaths and recovery were calculated referring to the total number of cases recorded in each country. As shown in Table 2, the countries of the Central Africa sub-region with the highest number of cases were Cameroon (21,793), Democratic Republic of Congo (11,372) and Angola (11,035) while Sao Tome and Principe had the smallest number of cases (962). Moreover, considering the total population of each country, the highest percentages of contamination cases were observed in Sao Tome and Principe (0.436%), Equatorial Guinea (0.358%) and Gabon (0.400%). In addition, relatively to the number of cases, the highest percentages of deaths (≥ 2%) were observed in Chad (6.742%), Democratic Republic of Congo (2.708%) and Angola (2.592%). Gabon, Equatorial Guinea and Cameroon had the highest recovery rates which were respectively 99.10%, 97.62% and 97.02% while the lowest recovery rates were observed in Central African Republic (RCA) (38.60%), Angola (53.40%) and Congo Brazzaville (73.48%).

In order to visualize the association between the parameters (population, number and percentage of cases, deaths, and recovered) reflecting the evolution of the pandemic in countries of the Central Africa sub-region, a principal component analysis was carried out. In an F1×F2 axis system (Fig. 11) the distribution of populations, number and percentages of cases, deaths, and recovered of COVID-19 recorded for Angola, Gabon, Equatorial Guinea, the RCA, Congo Brazzaville, RDC and Chad is represented. As seen in Fig. 11, for Cameroon, the number of cases and the percentage of recovered were closely related. This result means that, despite the high COVID-19 contamination cases of Cameroon, the proportion of death is low and most of contaminated persons recovered. Several hypotheses can justify these observations. First of all, the Bishop Samuel Kleda has developed a traditional medicine which was very efficient against COVID-19 and according to the Government and media reports, approximately 8,000 persons positive to COVID-19 were treated by the bishop medicine. During the pandemic period, consumption of some foods such as ginger, garlic and lemon has increased. That consumption was materialized by the ten-fold increase of the price of these food items on markets during that period. Lemon is rich in vitamin C and several studies reported the immune-boosting properties of vitamin C and their potential in the management of COVID-19 [31]. Some phenolic compounds commonly found in garlic (*Allium sativum*) and ginger (*Zinziber officinale*) such as quercetin and kaempferol were shown as antiviral agents due to their ability to inhibit the enzymatic activity of SARS 3-chymotrypsin-like protease (3CLpro), a vital enzyme for the replication of SARS-CoV [32]. Another approach to manage COVID-19 in Cameroon was the consumption of aqueous extracts of *Cinchona succirubra* bark (locally called "quinquina") and Vernonia leaves (locally called "ndole"). These extracts contained the active principle (quinine chlorhydrate and cinchonine) [33,34] of a medicine which was used in the management of malaria and which is found in chloroquine, an efficient anti-COVID-19 medicine [35]. However, further studies should be performed in order to confirm these hypotheses.

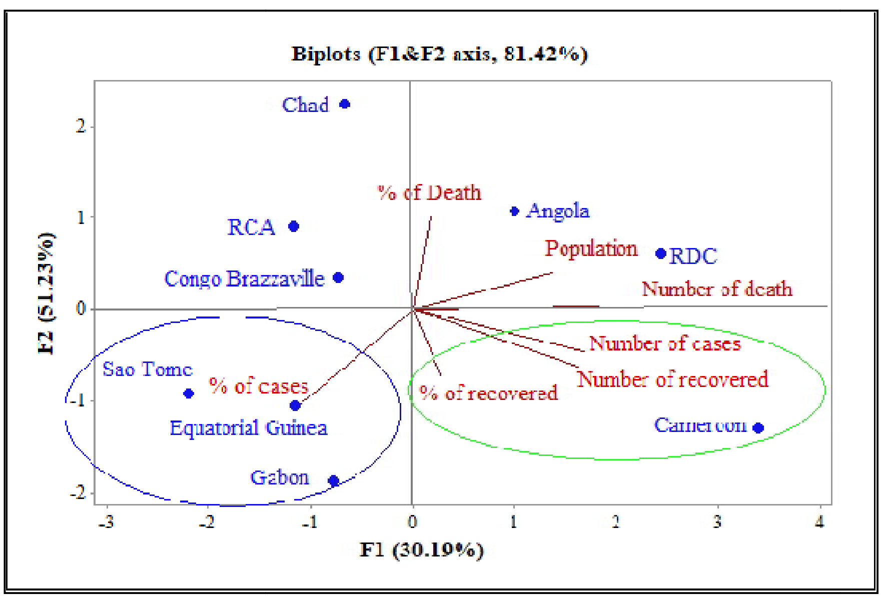

Fig. 11. Distribution of populations, number and percentages of cases, deaths, and recoveries of COVID-19 in Central Africa sub-region countries

RCA=Republic of Central Africa; RDC=Democratic Republic of Congo

Table 1. Correlation analyses and summary of trend equations and accuracy measures

Countries		Trend equations	MAPE	MAD	MSD	Spearman Rho	p-value
Angola	Cases	Yt = -294 + 35.33×t	913.00	197.30	78042.40	0.954	0.0000*
	Deaths	Yt=-4.33 + 0.7282×t	107.14	3.63	25.91		
Cameroon	Cases	Yt = 666 - 2.4×t	2467.00	476.00	379984.00	0.744	0.0001*
	Deaths	Yt =19.13 - 0.388×t	210.73	11.01	214.02		
Chad	Cases	Yt = 47.9 - 0.218×t	303.68	38.47	2507.84	0.775	0.0000*
	Deaths	Yt= 5.02 - 0.1169×t	65.62	3.42	25.41		
Congo B.	Cases	Yt = 85.8 + 3.99×t	544.50	130.70	28055.60	0.665	0.0000
	Deaths	Yt =2.36 + 0.0199×t	78.54	2.43	13.64		
E. Guinea	Cases	Yt = 142 + 0.70×t	1691.00	231.00	220836.00	0.042	0.8170
	Deaths	Yt = 1.72 + 0.047×t	69.73	4.19	73.62		
Gabon	Cases	Yt = 321.4 - 3.29×t	2282.20	231.70	76007.80	0.745	0.0000*
	Deaths	Yt =2.385 - 0.0439×t	44.34	1.54	5.16		
RCA	Cases	Yt = 200.1 - 3.25×t	1977.20	166.00	46849.40	0.695	0.0000*
	Deaths	Yt = 2.18 - 0.0202×t	56.06	2.56	16.63		
RDC	Cases	Yt = 396 - 3.93×t	387.10	238.30	85842.10	0.590	0.0002*
	Deaths	Yt = 9.03 - 0.013×t	127.26	6.74	68.88		
Sao Tome & P.	Cases	Yt = 51.0 - 1.27×t	408.95	39.36	4328.87	0.371	0.0360*
	Deaths	Yt=1.095-0.0379×t	53.82	0.57	0.62		

RCA=Central Republic of Africa, RDC=Democratic Republic of Congo, Congo B.=Congo Brazzaville, E. Guinea=Equatorial Guinea, Sao Tome & P.=Sao Tome and Principe.
**=significant at p<0.05*

Table 2. Percentage of cases, deaths and recovered in the countries of Central Africa sub-region

Countries	Population	Cases	Deaths	Recovered	%Cases	%Deaths	%Recovered
Angola	33,220,108	11035	286	5893	0.033%	2.592%	53.40%
Cameroon	26,776,416	21793	425	21143	0.081%	1.950%	97.02%
Chad	16,589,510	1498	101	1340	0.009%	6.742%	89.45%
Congo B	5,565,493	5290	92	3887	0.095%	1.739%	73.48%
E Guinea	1,418,901	5078	83	4957	0.358%	1.635%	97.62%
Gabon	2,244,088	8968	55	8887	0.400%	0.613%	99.10%
RCA	4,859,344	4868	62	1879	0.100%	1.274%	38.60%
RDC	90,504,645	11372	308	10749	0.013%	2.708%	94.52%
Sao Tome & P.	2,205,90	962	15	908	0.436%	1.559%	94.39%

RCA=Central Republic of Africa, RDC=Democratic Republic of Congo, Congo B.=Congo Brazzaville, E. Guinea=Equatorial Guinea, Sao Tome & P.=Sao Tome and Principe

Countries such as Sao Tome, Equatorial Guinea and Gabon were associated with the percentage of positive cases. This is justified by the highest percentages of positive cases recorded in these countries (0.436, 0.358 and 0.400%, respectively). However, despite all these observations, the threat of COVID-19 in the Central Africa sub-region was generally low and similar to the observations of Bankole et al. [6] for the West Africa sub-region. Various reasons are regularly mentioned to explain the low COVID-19 threat in Africa. Diop et al. [36] suggested that one of the factors that could explain the low spread of the virus in Africa is demography, especially the age of the population. Indeed, in most severely affected countries, the elderlies are the most affected [37]. However, in Africa, 60% of the population is under 25 years old and the median age is more than two times lower (19.7 years) than in Europe (42.5 years) [14]. In addition to the young population, the density of the continent should also be considered because, with nearly 45 inhabitants per Km^2 on average, Africa in general is much less populated than the European Union (121), East Asia (131) or South Asia (380). Moreover, some researchers such as Elisabeth Carniel, Director of the Centre Pasteur in Cameroon and the Cameroonian epidemiologist Yap Boum, believe that the regular exposure of African populations to various pathogens could have strengthened their immune system and their resistance to this virus. However, to date, no study has been performed to confirm such a hypothesis. Other researchers believe that treatments with chloroquine or BCG vaccine could promote the immunity of most of the African population against COVID-19 [12,38]. However, randomized controlled trials are needed to provide the highest quality proof for the hypothesis that BCG vaccination may protect against COVID-19 [38]. Otherwise, the epidemics that African countries have experienced over the years may also have played a role in the management of COVID-19. Indeed, the practices and actions implemented in Africa during previous health crises, such as Ebola or malaria, have contributed, in part, to limit the spread of the virus although the modes of transmission are totally different. Indeed, as soon as the first cases were registered, most of the Central Africa sub-region countries systematically closed the borders, proceeded to detection, isolation and care of COVID-19 detected cases, intense communication on hygiene and barrier measures. However, the limited means of these countries have raised many questions and some authors have indicated without giving tangible evidence that the low incidence of COVID-19 in Africa could be due to underreporting of cases [6]. It seems obvious that whether there is an under-report or not, the African countries are much less affected than the other countries and the reasons mentioned above could constitute elements of the answer to this enigma although deeper investigations are necessary. The main limitation of this study could be the high number of underreporting cases associated to financial limitation and the lack of testing.

4. CONCLUSION

The overall prevalence and incidence of COVID-19 are low in the countries of the Central Africa sub-region despite the problems facing the health systems of these countries. The low incidence observed in most countries in this region is probably not linked to the health care system and other explanations have been mentioned, including the regular intake of antimalarials and traditional medicines which were efficient for the management of COVID-19, a globally young population, effective preventive measures, previous "formative" epidemics and a certain immunity of the population, a virus which could arrive later or even underreported cases. However, so far, no formal evidence confirming the underreporting of cases exists and further studies need to be carried out to confirm or refute this hypothesis. In addition, it is strongly recommended to Central Africa sub-region countries and African countries, in general, to enhance their healthcare systems in order to better cope with daily health problems, new emerging diseases and eventually new major health crises.

DISCLAIMER

The products used for this research are commonly and predominantly use products in our area of research and country. There is absolutely no conflict of interest between the authors and producers of the products because we do not intend to use these products as an avenue for any litigation but for the advancement of knowledge. Also, the research was not funded by the producing company rather it was funded by personal efforts of the authors.

CONSENT

It is not applicable.

ETHICAL APPROVAL

It is not applicable.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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