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COVID-19: Correlation between gross domestic product, number of tests, and confirmed cases in 13 African countries

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This study aimed to analyze the relationship between gross domestic product (GDP) *per capita*, the number of tests, and confirmed cases of COVID-19 in South Africa, Ivory Coast, Ghana, Kenya, Ethiopia, Morocco, Mozambique, Nigeria, Rwanda, Senegal, Togo, Tunisia, and Zimbabwe. The database data on COVID-19 *(coronavirus)* (GitHub platform) was the source of information on GDP *per capita*, the number of tests, and confirmed cases of COVID-19 on 19 July 2020. Data were subjected to the Kolmogorov-Smirnov test ($\alpha = 0.05$), comparisons of their values considering the countries, and a Pearson's correlation matrix. GDP *per capita*, the number of tests and confirmed cases of COVID-19 presented positive Pearson's correlations ($p < 0.05$ and $r > 0.5$). There is positive feedback between the number of tests and the number of cases. Also, the GDP *per capita* reveals that purchasing power is a catalyst for such a phenomenon. Consequently, countries with the highest number of tests also present the highest numbers of confirmed cases. The evidence suggests that economic power determines the volume of testing, which might affect the differences between the numbers of confirmed cases in these nations.

Key words: Gross domestic product (GDP) *per capita*, testing, confirmed cases, COVID-19, Africa.

INTRODUCTION

There has to be a surveillance and testing system not limited by financial constraints regarding public health management. However, it does not seem wise to ignore that African countries were the last to receive COVID-19 tests and register confirmed cases. It might be an oversimplification to link purchasing capacity to the

scarcity of tests because some tests were donated (WHO Regional Office for Europe, 2020; Ghebreyesus et al., 2020a, b), but there is a tremendous disparity between the quantities of tests in developed and developing countries. Intuitively, from a financial point of view, wouldn't it only be more sustainable for suppliers to sell to those who have more resources to purchase the tests? Moreover, in a gesture of provocation, would such an acquisition not increase the ability to detect SARS-CoV-2, which would result in a more significant number of positive cases?

The financial dynamics behind the detection of COVID-19 in Africa is undoubtedly complex due to several actors such as governments, the private sector, non-governmental organizations, and civil society, each contributing uniquely and following its interests. In Mozambique's case, the National Institute of Health (INS) conducts almost the entire testing process. However, private clinics have reported sporadic cases that send samples to foreign laboratories (Savana, 2020). The World Health Organization (WHO) and other entities have been supporting Mozambican authorities (Gebresillassie et al., 2020; Escritório das Nações Unidas para a Coordenação de Assuntos Humanitários, 2020; Comité Internacional da Cruz Vermelha, 2020). Regardless of the African country, the testing process follows two stages: the acquisition of the tests and the detection of SARS-CoV-2. A key question for reflection is which of these variables is affecting the others the most. In other words, is the purchase of more tests only revealing the number of cases of COVID-19, or is the frequency of confirmed cases causing countries to acquire more tests? Or are these two phenomena subject to a positive feedback process? This manuscript does not attempt to answer these questions. Instead, the paper postulates that gross domestic product (GDP) *per capita* influences the acquisition of tests and a consequent increase in the registration of positive cases, creating a false impression that the wealthier the country, the greater is the frequency of COVID-19 cases. This study aimed to analyze the relationship between the gross domestic product, number of tests and confirmed cases in South Africa, Côte d'Ivoire, Ghana, Kenya, Ethiopia, Morocco, Mozambique, Nigeria, Rwanda, Senegal, Togo, Tunisia, Zimbabwe on 19 July 2020. The findings will support policymakers, healthcare personnel, and researchers in their interventions, as they will make more informed decisions considering the allocation of resources as a response to COVID-19.

MATERIALS AND METHODS

The current study is quantitative, longitudinal and observational, based on statistical analysis of data freely available online.

Data collection

This analysis used data from the COVID-19 database *(coronavirus)* de Beltekian et al. (2020) (GitHub, São Francisco, Califórnia, Estados Unidos). These authors have compiled daily values of numbers of tests and confirmed cases from all countries in the world since the initial outbreak in China. The list also includes countries' GDP per capita in US dollars (US $). This study included the three variables in South Africa, Côte d'Ivoire, Ghana, Kenya, Ethiopia, Morocco, Mozambique, Nigeria, Rwanda, Senegal, Togo, Tunisia, Zimbabwe on 19 July 2020. These countries were the only ones with complete information in the database consulted, and the date was the most recent until the end of July with missing information in these countries. Recent estimates based on censuses from these countries (which are also in the database used for this study) indicate that the combination of populations in these countries comprises 622,132,603 inhabitants.

Statistical analysis

The statistical packages used in this study were Microsoft Excel 2016 ™ (Microsoft Corporation, Washington, United States), IBM SPSS 21 ™ (Armonk, New York, United States) and JASP 0.13.0.0 (Amsterdam University, Amsterdam, Netherlands). Kolmogorov-Smirnov tests with a significance level of 0.05, performed in SPSS, allowed verifying if all variables had a normal distribution. The different countries' GDP per capita values were represented in a bar graph, made in Excel, originating from a consensus average to highlight the average deviations' magnitudes. Pearson's correlations showed how connected are the three variables (GDP per capita, frequency of tests, and confirmed cases).

RESULTS

To understand the subsequent analyses, it is essential to bear in mind that WHO situation reports show that the number of new cases is growing exponentially in all countries considered in this study (Beltekian et al., 2020), and each country has different frequencies of confirmed cases (World Health Organization, 2020a). For example, on 27 July, South Africa had 445,433 cases, a frequency much higher than that followed - 40,532 cases - from Nigeria (World Health Organization, 2020b). A Kolmogorov-Smirnov analysis showed that the GDPs per capita of the countries analyzed do not have a normal distribution (p <0.001), so they are very different. Figure 1 shows the different GDP values *per capita* than the average value (the US $ 4,408.46). Most countries are below this figure, but some are above, especially South Africa.

Regarding the testing of COVID-19, the Kolmogorov-Smirnov analysis suggested that the differences were not significant (p = 0.053), but Figure 2 shows notable differences between extreme values. While South Africa and Morocco performed over 1 million tests, the remaining countries tested below 500 thousand, and the five countries with the lowest test frequencies did not
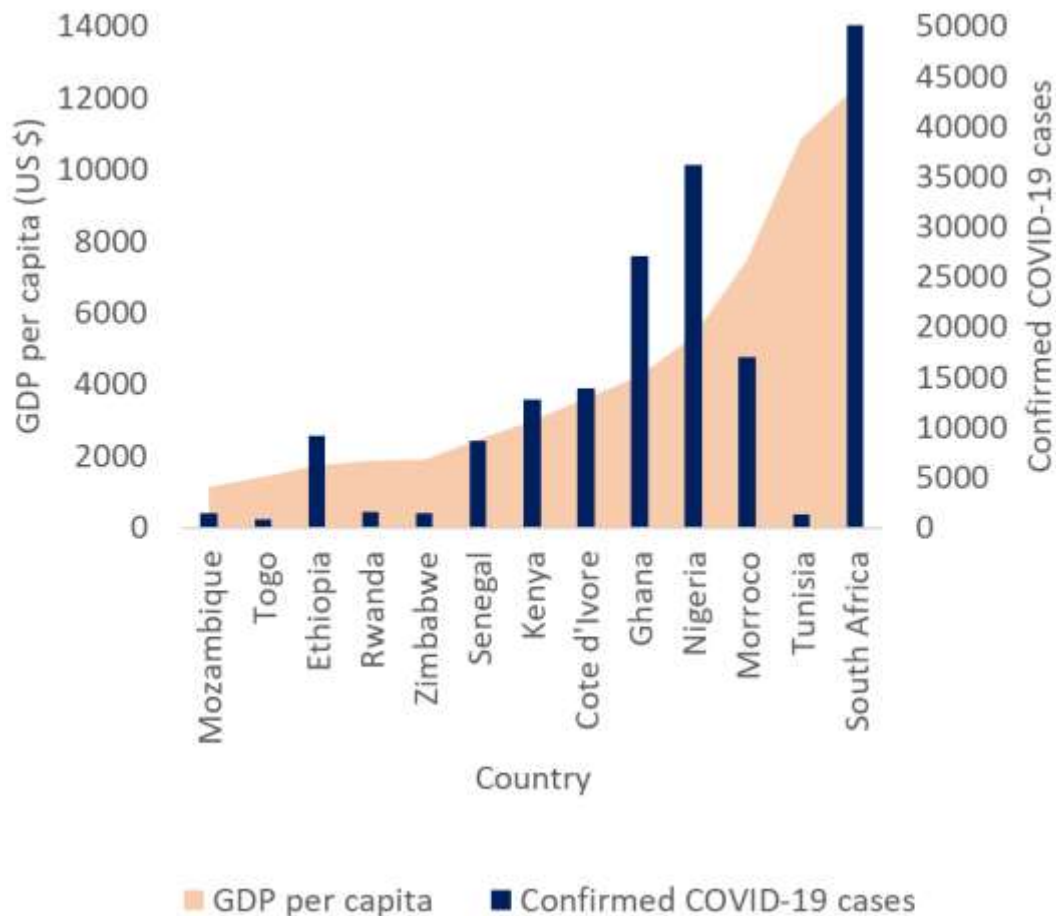
Figure 1. Differences between PIB per capita and also the number of COVID-19 confirmed cases in the African studies analyzed.

reach 100 thousand.

Figure 2 also shows how GDP per capita, number of tests, and confirmed cases are correlated, considering the countries under study. The correlation between the number of tests and cases was significant ($p < 0.001$), followed by GDP per capita and tests ($p = 0.007$), and finally followed by GDP per capita and cases ($p = 0.013$).

In any case, all were significant at $p < 0.05$. The three pairs of variables attributable to Pearson's r correlation above 0.5, which is mandatory, which is associated, and that the relationship between the three variables is of direct proportionality. These vacancies open space for less three possibilities: (1) countries with higher GDP per capita have greater purchasing capacity, acquiring more tests and obtaining more results, both negative and positive; (2) the high number of cases leads all countries to acquire more tests to continue testing and the greater financial capacity facilitates the acquisition of tests; (3) there is a vicious cycle, in which more tests result in more

records of positive cases, and such cases lead health services to request more tests, and in such a cycle, those who have greater purchasing capacity acquire more.

DISCUSSION

The present study analyzed the correlation of three factors - GDP per capita, number of tests, and the number of confirmed cases - of COVID-19 in 13 African countries. Social networks frequently raised suspicions that the WHO situation reports did not report the actual numbers of confirmed cases in Africa. The rationale behind such an idea is that Africa was the last to receive tests (Boakye-Agyemang and Oka, 2020; Gilbert et al., 2020; Makoni, 2020), mainly when it did not seem to be as affected as the others and how much was expected (Cambaza, 2020). This investigation tested the hypothesis that the number of confirmed cases in each country
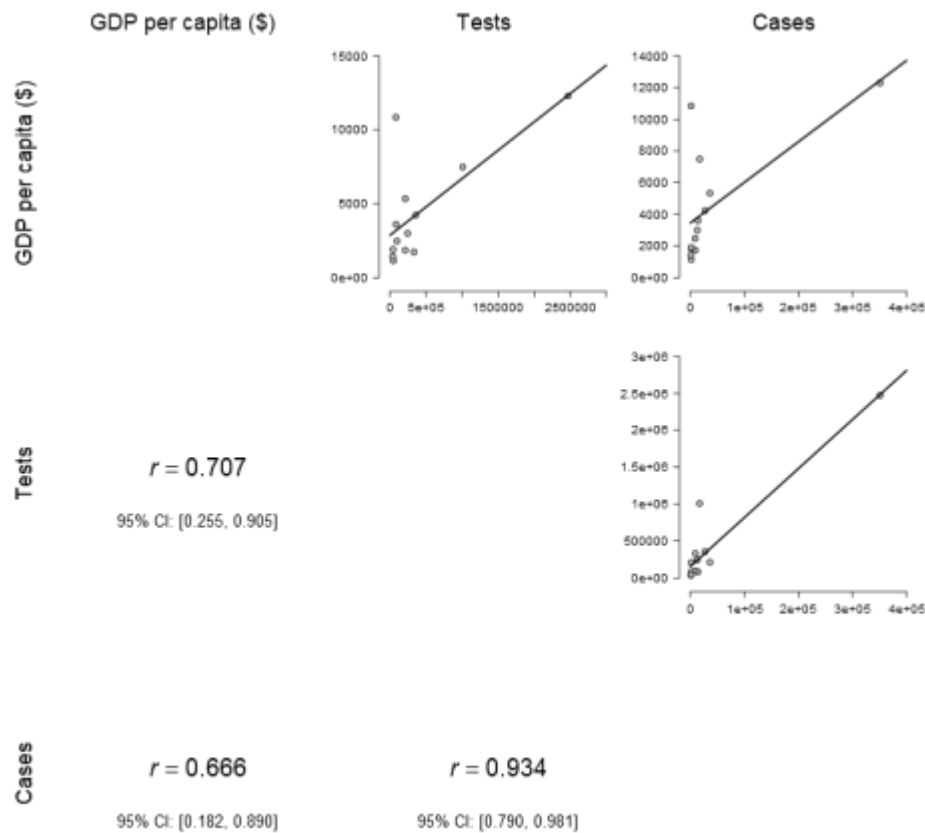
Figure 2. Correlations between GDP *per capita*, number of tests, and the frequency of confirmed cases of COVID-19 in African countries.

reflects its ability to purchase tests, thus measured through GDP per capita. First, GDP *per capita* varied significantly between countries (p <0.001), suggesting that this variable is unlikely to have caused ambiguity in the results. In other words, if countries have considerably different GDP per capita, there are no situations where the same GDP will correspond to different numbers of tests or confirmed cases.

Figure 1 shows that GDP *per capita* in South Africa, Morocco, Nigeria, and Tunisia were above the average compared to the other countries selected in the present study. This result reflects these countries' high economic growth due to the considerable industrialization and exportation of their products, not economic development. Economic growth is the increase in the productive capacity of a nation's goods and services, determined by the growth of GDP per capita, the growth rate of the labor force, the production of national revenue and constituted by the GDP growth rate per capita, by the growth rate of

the workforce in a given period and improvement of technology (Souza, 2005). However, for economic development to occur, growth must provide structural changes for the population, such as improved health, education, transport, culture and communication, and dynamism between world economies. Therefore, the fact that these same countries present GDP *per capita* above the mentioned average does not necessarily mean that they have a higher economic development level than the others. However, they have a specific economic power to acquire certain goods and services case. Testing is the basic principle for disease control, predominantly asymptomatic ones, because it is possible to place them in quarantine or isolation, thus preventing the virus's spread. Figure 2 concerning the number of tests, among the countries analyzed in this study, South Africa leads, followed by Morocco, countries with the highest GDP's per capita, with sufficient conditions to acquire the tests in quantities considerable.

Regarding the analysis of the relationship between the three selected variables, namely GDP per capita, number of tests, and confirmed cases, the results in Figure 2 show a significant and positive correlation between the variables, giving rise to three distinct possibilities mentioned in the results:

(i) "Countries with higher GDP per capita have greater purchasing capacity, acquiring more tests, and obtaining more results, both negative and positive." The high GDP per capita values are characteristic of countries with very active economic activity, where people are in constant movement (as in South Africa). In these places, the likelihood of contamination by the virus is more significant if there is no control. However, due to the high economic power, these countries can acquire more tests and reach more people, resulting in many confirmed cases. Therefore, countries' testing skills depend on their self-sufficiency, the health system, fiscal conditions, and social and political relationships (Anadolu Agency, 2020). Studies report a significant correlation between GDP per capita and the number of tests acquired and the number of confirmed cases of COVID-19. Therefore, in areas with high GDP, there should be a more significant prevention and control effort when there are epidemic outbreak cases, as is the case (Zhang et al., 2020; Shagam, 2020; Georank, 2020).

(ii) "The high number of cases leads all countries to acquire more tests to continue testing, and the greater financial capacity facilitates the acquisition of tests." Such a relationship results in a cycle that favors more developed countries with capital because the discovery of COVID-19 cases influences the acquisition of more tests, thus increasing the number of confirmed cases. In poor countries (many African countries), the control of this pandemic is limited by the insufficient number of tests, which in some cases are available for individuals who meet specific criteria, namely presenting symptoms of the disease, having been in contact with an infected person. Alternatively, come from a country with confirmed cases, which depends on donations from organizations (WHO, CDC, and others) or other countries with greater capacity, such as South Africa (Adepoju, 2020). Therefore, there might be some dependence on the acquisition of tests due to increased confirmed cases in a given region.

(iii) "There is a vicious cycle, in which more tests result in more positive case records, and such cases lead health services to request more tests, and in such a cycle, those who have the greatest purchasing capacity acquire more." Once again, it is clear that countries with the capital to do this are more likely to buy tests. However, to achieve the desired objectives (test all), the health system must be functional and organized. In such a situation, healthcare authorities distribute the same tests using known criteria, such as those who do not have a strong capacity to manage economic activities in places of high population concentration, such as markets and public transport stops. Therefore, there is a sequence relationship between GDP per capita - Number of tests - Number of confirmed cases of COVID-19, that is, the country's financial capacity, dictates the purchase of tests by countries with suspected cases of COVID-19 and performs tests according to defined standards. A more specific analysis between the number of tests and the number of confirmed cases of COVID-19 (Shagam, 2020). Therefore, it is clear that the number of confirmed cases in a region influences the number of tests. The more cases are detected, the more countries make efforts to obtain more tests to reach many people. As a consequence of this scenario, the countries with the highest number of tests performed are the ones with the largest number of confirmed cases so far.

Thus, this study recommended analyzing the correlation between GDP per capita, the number of tests, and confirmed cases of COVID-19 in thirteen African countries. Suppose GDP per capita shows an acceptable and positive correlation with the other variables ($r = 0.5$). In that case, it is reasonable to assume that the frequency of positive cases of COVID-19 in selected countries merely reflects their ability to purchase tests.

Conclusion

With the analyses and discussions presented, there is sufficient evidence to conclude that GDP, the number of tests, and confirmed cases of COVID-19 are significantly correlated. GDP per capita determines purchasing power for tests, facilitating the confirmation of more cases of COVID-19. Naturally, South Africa is the clearest case of this hypothesis, with a higher GDP per capita, a more significant number of tests, and as a consequence, a more significant number of confirmed cases. The high pressure of economic activities in countries with high GDP per capita leads to more frequent contact between people, causing more significant contamination. It is evident that the critical tool for controlling and preventing COVID-19 is testing, but more importantly is acquiring these tests.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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