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Title: COVID-19 and Mortality: A Statistical Analysis of African Countries

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Abstract

Introduction

The current COVID-19 pandemic is a global threat. This elicits questions on the level of preparedness and capacity of health systems to respond to emergencies. Relative to other parts of the world, Africa has poorly developed health systems with limited capacity to respond to health crises. Africa is particularly disadvantaged.

Methods

This cross-sectional study uses publicly available core health data for 53 African countries, to determine risk factors for cumulative COVID-19 deaths and cases per million in all countries in the continent. Descriptive statistics were determined for the indicators and a negative binomial regression was used for modelling the risk factors.

Results

In Sub-Saharan Africa, an increase in the number of nursing and midwifery personnel decreased the risk of COVID-19 deaths ($p=0.0178$) while a unit increase in UHC index of service coverage and prevalence of insufficient physical activity among adults increased the risk of COVID-19 deaths ($p=0.0432$ and $p=0.0127$). An increase in the proportion of infants initiating breastfeeding reduced the number of cases per million ($p<0.0001$) while an increase in higher healthy life expectancy at birth increased the number of cases per million ($p=0.0340$).

Conclusion

Despite its limited resources, Africa's preparedness and response to the COVID-19 pandemic can be improved by identifying and addressing *specific* gaps in the funding of health services delivery. These gaps impact negatively on service delivery but appear to have received limited funding and policy priority.

Article Summary

a. Strengths of the study:
    i. Use of a robust statistical analysis method
    ii. Identification of key evidence-based factors that might mitigate COVID-19 deaths and infections in Africa.
    iii. Identification of a significant factor in the population which may offer protection against COVID-19.
    iv. Innovative use of publicly available data which can easily be accessed and verified
b. Limitations of the study:
    i. Some countries had missing data in some of the indicators analyzed.
    ii. Use of multiple imputation technique which may have caused a slight overestimate of the variance

Introduction

In January 2020, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) popularly referred to as COVID-19 was identified as the cause of unknown pneumonia in Wuhan, China. Two months later the World Health Organisation (WHO) classified COVID-19 as a pandemic. COVID-19 is a global health threat. Since March 2020, there has been a rapid increase in the number of cases globally. As of June 16th 2020, there had been more than 7.8 million confirmed cases and 431,541 deaths and the numbers continue to rise exponentially. [1 2] In a bid to stop the virus spreading, there has been a global restriction on all activities.[3 4] The economic impact of a global shutdown and pressure on frail health systems of many countries across the world presents great uncertainty for the remaining half of the year and the immediate future.

The United States of America, Brazil, the United Kingdom and countries in Western Europe notably Italy, Spain and France account for the highest number of COVID-19 cases and mortality.[2] With the possible exception of Brazil, these countries have advanced health systems, reliable epidemic surveillance and response systems and have been able to mobilize resources with which to respond. However, due to the sudden increase in demand for health personnel, test kits, emergency care equipment and personal protective equipment, the health systems of all affected countries have been put under significant strain. With varying efficacy, the affected countries have increased hospital facilities for critical cases, increased the daily number of tests to identify positive cases and increased provision of personal protective equipment (PPE) for health personnel. [4 5]

At present, in comparison to the USA, and Europe, Africa has a lower number of cases and lower daily increase in infection. While this may seem an advantage, the WHO continues to express concern about the impact COVID may have on Africa. This is because, from the perspective of capacity, African countries are in a parlous situation relative to Europe, North America and some parts of Asia. The health systems of many African countries have limited ability to roll out widespread community screening and testing, few health personnel, and limited emergency facilities to manage critically ill COVID-19 patients [6]. And the easing of restrictions on social and economic activities is likely to lead to an increase in the number of cases of COVID-19 in African countries. So with the best will and effort, African countries cannot use the same methodology to respond and contain the pandemic to the level of the developed countries that have performed badly, let alone to that of those that have performed well. If they are to use their limited capacity efficiently, it is imperative African countries clearly identify factors that will support that objective and institute effective evidence-based approaches to managing COVID-19. Accordingly, in a bid to support focus on efficient capacity development, this study analyzes the relationship between health indicators and COVID-19 deaths and cases in African countries. It is the first paper of this type from Africa.

Methodology

Data Source

This is a cross-sectional study that has used data extracted from the World Health Organisation Global Health Observatory Repository.[7] Before extraction, the research team reviewed available indicators in the 2018 Global Reference List of 100 Core Health Indicators (plus health-related SDGs) [8] and listed different indicators by thematic areas. These indicators directly or indirectly describe the ability of a country's health system to respond to the health needs of the population. Data on confirmed cases of coronavirus and deaths were obtained from the Worldometer Coronavirus Live Update.[9]

Definition of variables

BCG immunization coverage among 1-year olds (%): BCG immunization coverage among 1-year olds (%).[10]

Nursing and midwifery personnel (per 10 000 population): It is the density of nurses and midwifery personnel per 10 000 people.[10]

UHC index of service coverage: Coverage of essential health services such as reproductive, maternal, newborn and child health amongst others.[10]

Prevalence of insufficient physical activity among adults aged 18+ years: Insufficient physical activity was defined as adults not meeting the WHO recommendations on physical activity for health i.e, at least 150 min of moderate-intensity, or 75 min of vigorous-intensity physical activity per week, or any equivalent combination of the two.[11]

Early initiation of breastfeeding (%): Initiation of breastfeeding within the first hour of birth and exclusively breastfed for the first six months of life.[12]

Healthy life expectancy at birth (years): This is a life expectancy estimate that applies disability weights to health states to compute the equivalent number of years of good health that a new born can expect.[13]

Prevalence of overweight among adults: Adults with a body mass index ≥ 30.

Current health expenditure (CHE) as a percentage of gross domestic product (GDP): This indicates the level of resources channelled to health relative to other uses.[10]

Data Management

Data for 32 indicators (or variables) from 12 thematic areas was extracted from the 2018 Global Reference List of 100 Core Health Indicators. The 12 thematic areas are Mortality by Age and Sex, Mortality by Cause, Morbidity, Nutrition, Environmental Risk Factors, Non-Communicable Diseases, Immunization, Essential health services, Utilization and access, Health workforce, Health Information and Health financing.

Data were extracted in .xls format for each variable and imported into STATA 15.0 software (StataCorp LLC College Station, TX). For each variable, the most recent data for all countries included in the study was retained with the corresponding year and country name and saved in .dta format. The different variables were merged using the country name as the unique identifier to obtain the final data set used for the analysis. The countries were further categorized into their assigned WHO region and World Bank income group.

Statistical methodology

All data on health indicators were continuous and were analysed descriptively using medians, interquartile ranges (IQR) and the range of the measures were determined by the minimum and maximum values.

Of the 53 countries included in the analysis, there were varying proportions of missing data with the majority missing less than 10% of the data. To address this, we assumed a missing at random mechanism and applied a multiple imputation technique with ten imputations and summarised the results across all the datasets. The fit of the multiple imputation was evaluated using variance information measures including relative efficiency.

Due to its flexibility in allowing for overdispersion, risk factors for cumulative COVID-19 deaths and cases per million were fitted using the negative binomial regression. Both univariate and multivariate regression models were fitted. In the multivariate model. A full model was fitted first and then structurally reduced using the backward selection procedure to arrive at the final model. Regression models were fitted for sub-Saharan Africa followed by all the countries in the continent. Model fit was assessed using the ratio of the deviance, scaled deviance, Pearson Chi-square and scaled Pearson Chi-square divided by the degrees of freedom. Additionally, we also assessed model fit using the cumulative sum of residual plots with 10 000 replications. Deaths and cases per million were those reported in the Worldometer as of 29th May 2020.

All statistical analysis was conducted using SAS Enterprise Guide 7.15 (SAS Institute Inc., NC, USA) using the procedures MEANS, GENMOD, MI, MIANALYZE.

Results

Characteristics

A total of 53 countries from Africa were included in this analysis (Table 1). The median number of cumulative COVID-19 deaths across the African continent was 12 (IQR: 3-49), cumulative deaths per million [2, IQR:0.2-6.0], cumulative COVID-19 cases [820, IQR: 295-2216], cumulative cases per million [63, IQR: 17.0-243.0], current health expenditure was 5.3 (IQR: 3.9-6.9) and BCG immunisation coverage in 1-year olds was 91.5% (IQR: 84.0-96.5). The median life expectancy was 63.2 years (IQR: 59.8-66.1), healthy life expectancy [55.7 years, IQR: 52.3-57.9] medical doctors per 10 000 population was 1.6 (IQR: 0.8-4.0)], nursing and midwifery personnel per 10 000 was 8.8 (IQR: 4.4-15.5),) and universal health care (UHC) index of service coverage 0.5 (IQR: 0.4-0.5).

Risk factors for sub-Saharan Africa

Cumulative COVID-19 deaths

In the multivariate regression, modelling risk factors for COVID-19 deaths in sub-Saharan Africa and controlling for BCG immunization coverage, a unit increase in the number of nursing and midwifery personnel decreased the risk of death by 0.0426 (p=0.0178) whereas a unit increase in the UHC index of service coverage and prevalence of insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 deaths by 4.7049 (p=0.0432) and 0.0830 (p=0.0127) respectively.

Cumulative Cases per Million
A unit increase in the proportion of infants initiating breastfeeding reduces the number of cases per million by 0.0563 (p<0.0001) whereas an increase in higher healthy life expectancy at birth increases the number of COVID-19 cases per million by 0.0417 (p=0.0340).

Risk factors for all the African countries
Cumulative COVID-19 deaths
Early initiation of breastfeeding (Beta= -0.0514, p-value=0.0027) was associated with a lower risk of death whereas increasing healthy life expectancy at birth was associated with a higher risk of death (Beta=0.1059, p-value=0.0285).

Cumulative cases per million
An increase in the current health expenditure as a percentage of GDP (Beta=-0.1739, p-value=0.0397) and the percentage initiated early on breastfeeding (Beta=-0.0460, p-value=0.0061) was associated with a decrease in cases of COVID-19 per million

Discussion

This study considers the factors associated with COVID-19 deaths and infection cases per million from 53 of 54 African countries.

In summary, our findings are that, controlling for BCG immunization coverage in sub-Saharan Africa, building health capacity by increasing the number of nursing and midwifery personnel will reduce COVID-19 deaths. However, we also find that higher UHC index of service coverage and prevalence of insufficient physical activity in adults ≥ 18 years increases fatalities. Additionally, having a population with a high proportion of people where breastfeeding had been initiated early, provided protection. A higher healthy life expectancy increased the risk of cases. This is not paradoxical but may point to the fact that the number of people who could contract the virus is augmented by longer life expectancy. When evaluating all the African countries, the initiation of early breastfeeding was protective against death whereas higher healthy life expectancy increased the risk of death. We also find that an increase in current health expenditure levels provide additional protection against COVID-19 infections.

Delving deeper into our results, the finding that an increase in the number of nursing and midwifery personnel reduced the risk of COVID-19 related mortality in sub-Saharan Africa echo findings from other parts of the world where the benefits of preparedness and available capacity has been shown to confer benefits in the management and care of patients.[14 15] Where capacity shortages exist in the health sector, there is potential for poor outcomes in the management and care of COVID-19 patients. Major gaps still exist in the implementation of the WHO International Health Regulations, notably increasing capacity of hospitals and appropriate injection of financial resources.[15] The results confirm the point made earlier that unlike the other COVID-19 affected parts of the world, Africa has less capacity to handle a major outbreak of COVID-19. Therefore,

African governments will need to strengthen their overall health care systems and in doing so, specific focus needs to be placed on enhancing human resource capacity such as nurses, medical doctors and laboratory personnel.

Our findings also illustrate that a higher UHC index of service coverage increases the risk of fatalities. While counter-intuitive, this may be driven by the countries in sub-Saharan Africa with the largest economies that have also had the largest number of cases and mortality: South Africa and Nigeria. A large number of people from these two countries travel internationally, in particular to Europe and it is likely that they have contracted the disease there and have imported it back into their countries.[16] To assess the robustness of this finding, we conducted a sensitivity analysis by removing the data on South Africa and Nigeria and re-estimated the model. No major differences relative to the first regression were observed.

Additionally, that cohort of the population that travels internationally is generally able to afford COVID-19 test kits and conduct more tests. Testing is a critical requirement for effective management of COVID-19. Additionally, from a statistical perspective, testing identifies cases (which might otherwise have been unobserved) and severe cases result in deaths - which are then more accurately recorded. This increases the number of observations on deaths. This view is similar to that reported in a previous paper on the vulnerability of African countries to COVID-19 and their preparedness to mitigate.[16]

More intuitively, we find that insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 mortality. It is well documented in the literature that the lack of physical activity increases the risk of obesity.[17] Recent publications on COVID-19 related mortality, have shown that obesity elevates the risk of mortality.[18 19] We postulate that the population of Africans aged 18+ years who do not undertake sufficient physical activity may be similarly at high risk of mortality.

We also found that where a large population is exposed to early initiation of breastfeeding, there was protection against COVID-19 infection. Research on the long-term benefits of breastfeeding is growing and recent evidence suggests a protective effect against some chronic diseases in adulthood.[20 21] It may be that this protective effect extends to non-severe cases of COVID-19.

Further, in sub-Saharan Africa and all the African countries combined, higher healthy life expectancy (life expectancy that accounts for disabilities) in this study was associated with a higher risk of COVID-19 infection. Our findings are in tandem with previously published work on risk factors for COVID-19 infection from around the world that have shown older people at higher risk for COVID-19 infection. Being older is associated with lower immunity and inflammatory reactions and a higher risk of comorbidities such as diabetes and hypertension amongst others. Such factors predispose older cohorts of the population to COVID-19 infection.

In conclusion, this analysis is based on publicly available information. This negated the need to implement some standard procedures associated with non-public data such as

sampling, study design and data collection. And to control for these limitations and alleviate any potential bias, we applied the robust statistical methods described above. Our study confirms that an increase in current health expenditure reduces the risk of COVID-19 infection. This finding is consistent with widely reported results [15]. And, in line with WHO International Health Regulations, some African governments have indeed increased the proportion of the budget allocated to health.[15 22] However, often, this investment is not only insufficient, but is also inefficiently allocated. Therefore, a salient contribution of this paper is that, identification of the key evidence-based factors that might mitigate COVID-19 deaths and infections will improve national health budget allocative efficiency. This will enhance the capacity for African countries to combat the pandemic.

Patient and public involvement

This study utilised publicly available health indicators and aggregated COVID-19 cases and deaths. No patients were involved.

Funding

No funding was available for this study.

Contributorship Statement

CO developed the initial research concept, developing the hypothesis and methodology. VW did the data extraction and merging of the different data sets. KO participated in developing the hypothesis and conducted the data analysis. All the authors participated in interpreting the results and writing the manuscript.

Data sharing statement

Data used for the analysis in this manuscript is publicly available and can be accessed at the referenced websites. Further enquiries and requests for the data used in this paper can be made through sending an email to otwombek@phru.co.za.

Ethics, Funding and Data Sharing

1. This study did not require ethical clearance as the data used for analysis is publicly available. Precautions were, however, adopted to document steps taken during data extraction, cleaning and analysis.
2. This manuscript did not receive funding from any organization and the authors declare no competing interest.

Dryad identifier

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Table 1: Descriptive summary of key health system indicators for African countries

Variables	Number of countries	Median (IQR)	Minimum-Maximum
Cummulative COVID-19 deaths	53	12.0 (3.0-49.0)	0.0- 1088.0
Cummulative COVID-19 deaths per million	53	2.0 (0.2-6.0)	0.0-55.0
Cummulative COVID-19 cases	53	820.0 (295.0-2216.0)	0.0- 37525.0
Cummulative COVID-19 cases per million	53	63.0 (17.0-243.0)	0.0-3987.0
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	52	5.3 (3.9-6.9)	2.8-13.4
BCG immunization coverage among 1-year-olds (%)	52	91.5 (84.0-96.5)	52.0-99.0
Early initiation of breastfeeding (%)	46	51.4 (35.7-65.3)	23.0-93.1
Life expectancy at birth (years)	52	63.2 (59.8-66.1)	52.9-76.4
Healthy life expectancy (HALE) at birth (years)	52	55.7 (52.3-57.9)	44.9-66.3
Medical doctors (per 10 000 population)	51	1.6 (0.8-4.0)	0.1-25.3
Nursing and midwifery personnel (per 10 000 population)	51	8.8 (4.4-15.5)	0.1-80.8
Hospital beds (per 10 000 population)	51	10.0 (5.0-18.0)	1.0-36.0
UHC index of service coverage (SCI)	52	0.5 (0.4-0.5)	0.3-0.8
Prevalence of insufficient physical activity among adults aged 18+ years	45	22.1 (15.4-28.0)	5.5-41.3
Prevalence of overweight among adults	51	28.9 (26.2-36.8)	20.9-63.5
Incidence of tuberculosis (per 100 000 population per year)	52	175.0 (79.0-303.0)	12.0-611.0
Prevalence of HIV among adults aged 15 to 49 (%)	50	1.6 (0.7-4.6)	0.1-27.3

Table 2: Risk factors for COVID-19 deaths and cases per million

Variables	Univariate		Multivariate	
	Beta (Std. Error)	p-value	Beta (Std. Error)	p-value
a) Sub-Saharan Africa				
Risk factors for deaths				
BCG immunization coverage among 1-year-olds (%)	-.0302 (0.0189)	0.1106	-.0293 (0.0191)	0.1242
Nursing and midwifery personnel (per 10 000 population)	-.0324 (0.0343)	0.3467	-.0426 (0.0178)	**0.0171**
UHC index of service coverage (SCI)	4.8486 (1.7709)	0.0062	4.7049 (2.3268)	**0.0432**
Prevalence of insufficient physical activity among adults aged 18+ years	0.1201 (0.0243)	<.0001	0.0830 (0.0333)	**0.0127**
Risk factors for cases per million				
Early initiation of breastfeeding (%)	-.0534 (0.0143)	0.0002	-.0563 (0.0136)	**<.0001**
Healthy life expectancy (HALE) at birth (years)	0.0917 (0.0410)	0.0251	0.0870 (0.0415)	**0.0373**
Prevalence of overweight among adults	0.0958 (0.0390)	0.0140	0.0417 (0.0340)	0.2214
b) All the African countries				
Risk factors for deaths (all countries)				
Early initiation of breastfeeding (%)	-.0437 (0.0183)	0.0205	-.0514 (0.0171)	**0.0027**
Healthy life expectancy (HALE) at birth (years)	0.0865 (0.0465)	0.0626	0.1059 (0.0483)	**0.0285**
Risk factors for cases per million (all countries)				
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	-.1913 (0.0896)	0.0328	-.1739 (0.0845)	**0.0397**
Early initiation of breastfeeding (%)	-.0476 (0.0169)	0.0049	-.0460 (0.0167)	**0.0061**

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Text Section and Item Name	Section or Item Description	
Notes to authors	• The SQUIRE guidelines provide a framework for reporting new knowledge about how to improve healthcare • The SQUIRE guidelines are intended for reports that describe system level work to improve the quality, safety, and value of healthcare, and used methods to establish that observed outcomes were due to the intervention(s). • A range of approaches exists for improving healthcare. SQUIRE may be adapted for reporting any of these. • Authors should consider every SQUIRE item, but it may be inappropriate or unnecessary to include every SQUIRE element in a particular manuscript. • The SQUIRE Glossary contains definitions of many of the key words in SQUIRE. • The Explanation and Elaboration document provides specific examples of well-written SQUIRE items, and an in-depth explanation of each item. • Please cite SQUIRE when it is used to write a manuscript.	
Title and Abstract		
1. Title	Indicate that the manuscript concerns an initiative to improve healthcare (broadly defined to include the quality, safety, effectiveness, patient-centeredness, timeliness, cost, efficiency, and equity of healthcare)	Yes
2. Abstract	a. Provide adequate information to aid in searching and indexing b. Summarize all key information from various sections of the text using the abstract format of the intended publication or a structured summary such as: background, local problem, methods, interventions,	Adequate information searching and indexing included Summarized as per the checklist

	results, conclusions	

Introduction	*Why did you start?*	
3. Problem Description	Nature and significance of the local problem	Well described
4. Available knowledge	Summary of what is currently known about the problem, including relevant previous studies	Done
5. Rationale	Informal or formal frameworks, models, concepts, and/or theories used to explain the problem, any reasons or assumptions that were used to develop the intervention(s), and reasons why the intervention(s) was expected to work	Rationale is presented
6. Specific aims	Purpose of the project and of this report	Presented
Methods	*What did you do?*	
7. Context	Contextual elements considered important at the outset of introducing the intervention(s)	Yes this is presented
8. Intervention(s)	a. Description of the intervention(s) in sufficient detail that others could reproduce it b. Specifics of the team involved in the work	Sufficient detail is provided Specifics of the team provided
9. Study of the Intervention(s)	a. Approach chosen for assessing the impact of the intervention(s) b. Approach used to establish whether the observed outcomes were due to the intervention(s)	N/A
10. Measures	a. Measures chosen for studying processes and outcomes of the intervention(s), including rationale for choosing them, their operational definitions, and their validity and reliability b. Description of the approach to the ongoing assessment of contextual elements that contributed to the success, failure, efficiency, and cost c. Methods employed for assessing completeness and accuracy of data	a) and b) not applicable Part C: Methods assessing completeness and accuracy of data are presented
11. Analysis	a. Qualitative and quantitative methods used to draw inferences from the data b. Methods for understanding variation within the data, including the effects of time as a variable	Detailed analysis process is presented
12. Ethical	Ethical aspects of implementing and studying the intervention(s) and how they were addressed, including, but	N/A

Considerations	not limited to, formal ethics review and potential conflict(s) of interest	

Results	*What did you find?*	
13. Results	a. Initial steps of the intervention(s) and their evolution over time (*e.g.*, time-line diagram, flow chart, or table), including modifications made to the intervention during the project b. Details of the process measures and outcome c. Contextual elements that interacted with the intervention(s) d. Observed associations between outcomes, interventions, and relevant contextual elements e. Unintended consequences such as unexpected benefits, problems, failures, or costs associated with the intervention(s). f. Details about missing data	The results are presented in sufficient detail as achieved with the methods applied Associations are presented and described We clarify how we handle missing data
Discussion	*What does it mean?*	
14. Summary	a. Key findings, including relevance to the rationale and specific aims b. Particular strengths of the project	We present key findings in relation to the specific aims and context
15. Interpretation	a. Nature of the association between the intervention(s) and the outcomes b. Comparison of results with findings from other publications c. Impact of the project on people and systems d. Reasons for any differences between observed and anticipated outcomes, including the influence of context e. Costs and strategic trade-offs, including opportunity costs	We have interpreted our findings and put them in context
16. Limitations	a. Limits to the generalizability of the work b. Factors that might have limited internal validity such as confounding, bias, or imprecision in the design,	We present the limitations of our study in detail The strength of the

	methods, measurement, or analysis c. Efforts made to minimize and adjust for limitations	statistical method used is highlighted in this section
17. Conclusions	a. Usefulness of the work b. Sustainability c. Potential for spread to other contexts d. Implications for practice and for further study in the field e. Suggested next steps	This section was written in detail and covers points a) and d) and e).
Other information		
18. Funding	Sources of funding that supported this work. Role, if any, of the funding organization in the design, implementation, interpretation, and reporting	We provide a funding statement

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Title: Factors associated with COVID-19 infections and mortality in Africa: A cross-sectional study using publicly available data

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Abstract

Introduction

The current COVID-19 pandemic is a global threat. This elicits questions on the level of preparedness and capacity of health systems to respond to emergencies relative to other parts of the world.

Methods

This cross-sectional study uses publicly available core health data for 53 African countries, to determine risk factors for cumulative COVID-19 deaths and cases per million in all countries in the continent. Descriptive statistics were determined for the indicators and a negative binomial regression was used for modelling the risk factors.

Results

In Sub-Saharan Africa, an increase in the number of nursing and midwifery personnel decreased the risk of COVID-19 deaths ($p=0.0178$) while a unit increase in universal health care (UHC) index of service coverage and prevalence of insufficient physical activity among adults increased the risk of COVID-19 deaths ($p=0.0432$ and $p=0.0127$). An increase in the proportion of infants initiating breastfeeding reduced the number of cases per million ($p<0.0001$) while an increase in higher healthy life expectancy at birth increased the number of cases per million ($p=0.0340$).

Conclusion

Despite its limited resources, Africa's preparedness and response to the COVID-19 pandemic can be improved by identifying and addressing *specific* gaps in the funding of health services delivery. These gaps impact negatively on service delivery in Africa which requires more nursing personnel and increased UHC coverage to mitigate the effects of COVID-19.

Article Summary

a. Strengths of the study:
   i. Innovative use of credible publicly available data which can easily be accessed and verified
   ii. Use of multiple imputation technique to address missing observations in the different variables.
   iii. Use of robust negative binomial regression analysis method which allows for modeling of over-dispersion in the data.

b. Limitations of the study:
   i. Extracted data had missing observations which necessitated excluding some variables.
   ii. The methods used to impute for missing data may have overestimated the variance

Introduction

In January 2020, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) popularly referred to as COVID-19 was identified as the cause of unknown pneumonia in Wuhan, China. Two months later, the World Health Organisation (WHO) classified COVID-19 as a pandemic. COVID-19 is a global health threat. Since March 2020, there has been a rapid increase in the number of cases globally. Globally, as of 30th August 2020, there have been 24,822,800 confirmed cases of COVID-19, including 838,360 deaths, reported to WHO. [1 2] In a bid to stop the virus from spreading, there has been a global restriction on several activities including travelling.[3 4] The economic impact of a global shutdown and pressure on frail health systems of many countries across the world presents great uncertainty for the remaining half of the year and the immediate future.

The United States of America, Brazil, the United Kingdom and countries in Western Europe notably Italy, Spain and France account for the highest number of COVID-19 cases and mortality.[2] With the possible exception of Brazil, these countries have advanced health systems, reliable epidemic surveillance and response systems and have been able to mobilize resources with which to respond. However, due to the sudden increase in demand for health personnel, test kits, emergency care equipment and personal protective equipment, the health systems of all affected countries have been put under significant strain. With varying efficacy, the affected countries have increased hospital facilities for critical cases, increased the daily number of tests to identify positive cases and increased provision of personal protective equipment (PPE) for health personnel. [4 5]

At present, in comparison to the United States of America (USA), and Europe, Africa has a lower number of cases and lower daily increase in infection. While this may seem an advantage, the WHO continues to express concern about the impact COVID-19 may have on Africa. This is because, from the perspective of capacity, African countries are in a parlous situation relative to Europe, North America and some parts of Asia. The health systems of many African countries have limited ability to roll out widespread community screening and testing, few health personnel, and limited emergency facilities to manage critically ill COVID-19 patients [6]. The easing of restrictions on social and economic activities is likely to lead to a second wave of cases of COVID-19 in African countries. So with the best will and effort, African countries cannot use the same methodology to respond and contain the pandemic to the level of the developed countries that have performed badly, let alone to that of those that have performed well. If they are to use their limited capacity efficiently, it is imperative African countries clearly identify factors that will support that objective and institute effective evidence-based approaches to managing COVID-19. Accordingly, in a bid to support focus on efficient capacity development, this study analyzes the relationship between health indicators and COVID-19 deaths and cases in African countries. While the indicators were drawn from different thematic areas, our analysis was largely data driven. The analysis is conducted for sub-Saharan Africa (SSA) and entire continent since SSA is known to have a higher burden of disease.

Methodology

This is a cross-sectional study of the most recent 2020 data for African countries extracted from the World Health Organisation Global Health Observatory Repository.[7] Before extraction, the research team reviewed available indicators in the 2018 Global Reference List of 100 Core Health Indicators (plus health-related SDGs) [8] and listed different indicators by thematic areas. These indicators directly or indirectly describe the potential ability of a country's health system to respond to the health needs of the population and may further determine the extent available services can be expanded to accommodate emergencies. Data on confirmed cases of coronavirus and deaths were obtained from the Worldometer Coronavirus Live Update.[9]

Definition of variables

BCG immunization coverage among 1-year olds (%): BCG immunization coverage among 1-year olds (%).[10]

Nursing and midwifery personnel (per 10 000 population): It is the density of nurses and midwifery personnel per 10 000 people.[10]

UHC index of service coverage: Coverage of essential health services such as reproductive, maternal, newborn and child health amongst others.[10]

Prevalence of insufficient physical activity among adults aged 18+ years: Insufficient physical activity was defined as adults not meeting the WHO recommendations on physical activity for health i.e, at least 150 min of moderate-intensity, or 75 min of vigorous-intensity physical activity per week, or any equivalent combination of the two.[11]

Early initiation of breastfeeding (%): Initiation of breastfeeding within the first hour of birth and exclusively breastfed for the first six months of life.[12]

Healthy life expectancy at birth (years): This is a life expectancy estimate that applies disability weights to health states to compute the equivalent number of years of good health that a new born can expect.[13]

Life expectancy at birth: This reflects the overall mortality level of a population. It summarizes the mortality pattern that prevails across all age groups - children and adolescents, adults and the elderly.[14]

Prevalence of overweight among adults: Adults with a body mass index ≥ 30.

Current health expenditure (CHE) as a percentage of gross domestic product (GDP): This indicates the level of resources channelled to health relative to other uses.[10]

Statistical methodology

Data for 32 indicators (or variables) from 12 thematic areas were extracted from the 2018 Global Reference List of 100 Core Health Indicators (Table 1). The 12 thematic areas are Mortality by Age and Sex, Mortality by Cause, Morbidity, Nutrition, Environmental Risk Factors, Non-Communicable Diseases, Immunization, Essential health services, Utilization and access, Health workforce, Health Information and Health financing.

Data were extracted in .xls format for each variable and imported into STATA 15.0 software (StataCorp LLC College Station, TX). For each variable, the most recent data

for all countries included in the study were retained with the corresponding year and country name in .dta format. The different variables were merged using the country name as the unique identifier to obtain the final data set used for the analysis. The countries were further categorized into their assigned WHO region and World Bank income group except Somalia that had missing data.

All data on health indicators were continuous and were analysed descriptively using median, interquartile range (IQR) and minimum and maximum values.

Of the 53 countries included in the analyses, there were varying proportions of < 10% missing data. To address this, we assumed a missing at random mechanism and applied a multiple imputation technique with ten imputations and summarised the results across all the datasets.[15] The fit of the multiple imputation was evaluated using variance information measures including relative efficiency.

We reviewed the core indicators together with a clinician who advised on the more plausible ones to answer our hypothesis. The identified variables were subsequently subjected to various statistical approaches including testing for correlations and using variable selection regression procedures to arrive at the final list.

Due to its flexibility in allowing for overdispersion, risk factors for cumulative COVID-19 deaths and cases per million were fitted using the negative binomial regression. Both univariate and multivariate regression models were fitted. In the multivariate model, a full model including all the variables was fitted and the final model determined using the backward selection procedure. Regression models were fitted for sub-Saharan Africa followed by a sensitivity analyses including all the countries in the continent. Model fit was assessed using the ratio of the deviance, scaled deviance, Pearson Chi-square and scaled Pearson Chi-square divided by the degrees of freedom. Additionally, we also assessed model fit using the cumulative sum of residual plots with 10 000 replications. Deaths and cases per million were those reported in the Worldometer as of 29th May 2020.

All statistical analyses were conducted using SAS Enterprise Guide 7.15 (SAS Institute Inc., NC, USA).

Results

Characteristics

A total of 53 countries from Africa were included in this analysis (Table 2). The median number of cumulative COVID-19 deaths across the African continent was 12 (IQR: 3-49), cumulative deaths per million (2, IQR:0.2-6.0), cumulative COVID-19 cases [820, IQR: 295-2216], cumulative cases per million (63, IQR: 17.0-243.0), current health expenditure was 5.3 (IQR: 3.9-6.9) and BCG immunisation coverage in 1-year olds was 91.5% (IQR: 84.0-96.5). The median life expectancy was 63.2 years (IQR: 59.8-66.1), healthy life expectancy 55.7 years (IQR: 52.3-57.9), medical doctors per 10 000 population was 1.6 (IQR: 0.8-4.0), nursing and midwifery personnel per 10 000 was 8.8

(IQR: 4.4-15.5) and universal health care (UHC) index of service coverage 0.5 (IQR: 0.4-0.5).

Risk factors for sub-Saharan Africa

Cumulative COVID-19 deaths

In the multivariate regression, modelling risk factors for COVID-19 deaths in sub-Saharan Africa and controlling for BCG immunization coverage, a unit increase in the number of nursing and midwifery personnel decreased the risk of death by 0.0426 (p=0.0178) whereas a unit increase in the UHC index of service coverage and prevalence of insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 deaths by 4.7049 (p=0.0432) and 0.0830 (p=0.0127) respectively (Table 3).

Cumulative Cases per Million

A unit increase in the proportion of infants initiating breastfeeding reduces the number of cases per million by 0.0563 (p<0.0001) whereas an increase in higher healthy life expectancy at birth increases the number of COVID-19 cases per million by 0.0417 (p=0.0340).

Risk factors for all the African countries

Cumulative COVID-19 deaths

Early initiation of breastfeeding (Beta= -0.0514, p-value=0.0027) was associated with a lower risk of death whereas increasing healthy life expectancy at birth was associated with a higher risk of death (Beta=0.1059, p-value=0.0285).

Cumulative cases per million

An increase in the current health expenditure as a percentage of GDP (Beta=-0.1739, p-value=0.0397) and the percentage initiated early on breastfeeding (Beta=-0.0460, p-value=0.0061) was associated with a decrease in cases of COVID-19 per million (Table 3).

In the multiple imputation estimations, the relative efficiency of variables where imputation was conducted ranged from 95% to 99% whereas the scaled deviance values for the regression models were within the acceptable range.

Discussion

This study considers the factors associated with COVID-19 deaths and infection cases per million from 53 of 54 African countries. In summary, building health capacity by increasing the number of nursing and midwifery personnel will reduce COVID-19 deaths in sub-Saharan Africa. However, we also found that higher UHC index of service coverage and prevalence of insufficient physical activity in adults ≥ 18 years increases fatalities. Additionally, having a population with a high proportion of people where breastfeeding had been initiated early, provided protection. A higher healthy life expectancy increased the risk of cases. When evaluating all the African countries, the

initiation of early breastfeeding was protective against death whereas higher healthy life expectancy increased the risk of death. We also find that an increase in current health expenditure levels provide additional protection against COVID-19 infections.

Delving deeper into our results, the finding that an increase in the number of nursing and midwifery personnel reduced the risk of COVID-19 related mortality in sub-Saharan Africa echo findings from other parts of the world where the benefits of preparedness and available capacity has been shown to confer benefits in the management and care of patients.[16 17] Where capacity shortages exist in the health sector, there is potential for poor outcomes in the management and care of COVID-19 patients. Major gaps still exist in the implementation of the WHO International Health Regulations, notably increasing capacity of hospitals and appropriate injection of financial resources.[17] The results confirm the point made earlier that unlike the other COVID-19 affected parts of the world, Africa has less capacity to handle a major outbreak of COVID-19. Therefore, African governments need to strengthen the overall health care systems and in doing so, specific focus needs to be placed on enhancing human resource capacity such as nurses, medical doctors and laboratory personnel.

Our findings also illustrate that a higher UHC index of service coverage increases the risk of fatalities. While counter-intuitive, this may be driven by the countries in sub-Saharan Africa with the largest economies that have also had the largest number of cases and mortality: South Africa and Nigeria. A large number of people from these two countries travel internationally, in particular to Europe and it is likely that they have contracted the disease there and have imported it back into their countries.[18] To assess the robustness of this finding, we conducted a sensitivity analysis by removing the data on South Africa and Nigeria and re-estimated the model. No major differences relative to the first regression were observed suggesting that importation of infections similarly occurred in other sub-Saharan African countries.

Additionally, that cohort of the population that travels internationally is generally able to afford COVID-19 test kits and conduct more tests. Testing is a critical requirement for effective management of COVID-19. From a statistical perspective, testing identifies cases which may be managed before getting severe resulting in deaths. This increases the number of observations on deaths. This view is similar to that reported in a previous paper on the vulnerability of African countries to COVID-19 and their preparedness to mitigate.[18]

More intuitively, we find that insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 mortality. It is well documented in the literature that the lack of physical activity increases the risk of obesity.[19] Recent publications on COVID-19 related mortality, have shown that obesity elevates the risk of mortality.[20 21] Physical inactivity has long been recognized as a risk factor for non-communicable diseases which is a known cause of mortality globally (1, 2).[22 23] Early studies since the onset of the COVID-19 outbreak in China indicated elderly patients and those with co-morbidities particularly diabetes, hypertension and chronic respiratory diseases were at increased risk of mortality from COVID-19 (3, 4).[24 25] Therefore, the finding of

insufficient physical activity as a risk factor for death from our study is consistent with earlier studies (1).[23] Similarly, immunization has proved effective in prevention of different types of infectious diseases globally while breastfeeding provides babies with essential nutrients and antibodies to help prevent infections early in life. Hence, establishment of expanded program on immunization (EPI) and programs to encourage breastfeeding globally. Thus we postulate that the population of Africans aged 18+ years who do not undertake sufficient physical activity may be similarly at high risk of mortality.

We also found that where a large population is exposed to early initiation of breastfeeding, there was protection against COVID-19 infection. Research on the long-term benefits of breastfeeding is growing and recent evidence suggests a protective effect against some chronic diseases in adulthood.[26] [27] It may be that this protective effect extends to non-severe cases of COVID-19.

Further, in sub-Saharan Africa and all the African countries combined, higher healthy life expectancy (life expectancy that accounts for disabilities) in this study was associated with a higher risk of COVID-19 infection. Our findings are in tandem with previously published work on risk factors for COVID-19 infection from around the world that have shown older people are at higher risk for COVID-19 infection. Being older is associated with lower immunity and inflammatory reactions and a higher risk of comorbidities such as diabetes and hypertension amongst others. Such factors predispose older cohorts of the population to COVID-19 infection.

This study is not without limitations. The data used was sourced from publicly available repositories and therefore we had no control in sampling, study design and data collection processes. The study we conducted is cross-sectional and therefore cannot deduce causality. Since COVID-19 statistics are updated on a daily basis, the findings we report may vary with updated data. Despite these challenges, we applied robust statistical analysis methods to alleviate potential biases.

In conclusion, our study findings showed a relationship between COVID-19 cases and deaths with health capacity, breast feeding, life expectancy (as a proxy for age) and healthcare funding. Timely identification of the key evidence-based factors that might mitigate COVID-19 infections and deaths in Africa is pertinent for better management of the current and future pandemics. This may include investing in healthcare capacity building, infrastructure, disease surveillance, public health laboratories and all other aspects that relate to health as elucidated in the WHO International Health Regulations.[28]

Patient and public involvement
This study utilised publicly available health indicators and aggregated COVID-19 cases and deaths. No patients were involved.

Funding
No funding was available for this study.

Contributorship Statement
CO developed the initial research concept, developing the hypothesis and methodology. VW did the data extraction and merging of the different data sets. KO participated in developing the hypothesis and conducted the data analysis. All the authors participated in interpreting the results and writing the manuscript.

Data sharing statement
Data used for the analysis in this manuscript is publicly available and can be accessed at the referenced websites. Further enquiries and requests for the data used in this paper can be made through sending an email to otwombek@phru.co.za.

Ethics, Funding and Data Sharing
1. This study did not require ethical clearance as the data used for analysis is publicly available. Precautions were, however, adopted to document steps taken during data extraction, cleaning and analysis.
2. This manuscript did not receive funding from any organization and the authors declare no competing interest.

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Table 1: Summary of thematic areas of health indicators

Thematic Area	Indicators used
Mortality by age and sex	Life expectancy and healthy life expectancy at birth (years)
	Adult mortality rate between 15 and 60 years of age (Adult mortality rate (probability of dying between 15 and 60 years per 1000 population))
	Under-five mortality rate (per 1000 live births)
	Infant mortality rate (per 1000 live births)
	Neonatal mortality rate (per 1000 live births)
Mortality by cause	Maternal mortality ratio (Maternal mortality ratio (per 100 000 live births))
	TB mortality rate (per 100 000 population)
	AIDS-related mortality rate
	Mortality from unsafe water, unsafe sanitation and lack of hygiene
Morbidity	HIV prevalence rate (per 1000 population)
	HIV incidence rate (per 1000 population)
	TB incidence rate (per 100 000 population)
Nutrition	Exclusive breastfeeding rate 0–5 months of age (%)
	Early initiation of breastfeeding (%)
Environmental risk factors	Population using safely managed drinking-water services (%)
	Population using safely managed sanitation services (Also: population with handwashing facility with soap and water) (%)
	Air pollution level in cities (ug/m3)
Non-communicable diseases	Tobacco use among persons aged 15+ years [SDG 3.a.1] (Also: adolescents) (%)
	Raised blood pressure among adults (18+ %)
	Overweight and obesity in adults (Also: school-age children and adolescents) (%)
	Raised blood glucose/diabetes among adults (%)
	Insufficient physical activity in adults (Also: adolescents) (%)
Immunization	Immunization coverage rate by vaccine for each vaccine in the national schedule (%)
Essential health services	Coverage of essential health services (%)
Utilization and access	Health facility density and distribution (Also: access to emergency surgery) (per 10 000 population)
	Hospital bed density (per 10 000 population)
	Access to a core set of relevant essential medicines (%)
Health workforce	Health worker density and distribution (per 10 000 population)
Health information*	Completeness of reporting by facilities (Also: completeness and timeliness for notifiable diseases)
Health financing	Total current expenditure on health as % of gross domestic product (Also: total capital expenditure on health as % of current + capital expenditure on health)
	Public domestic sources of current spending on health as % of current health expenditure
	External source of current spending on health (% of current expenditure on health)

*Data not available

Table 2: Descriptive summary of key health system indicators for African countries

Variables	Number of countries	Median (IQR)	Minimum-Maximum
Cummulative COVID-19 deaths	53	12.0 (3.0-49.0)	0.0- 1088.0
Cummulative COVID-19 deaths per million	53	2.0 (0.2-6.0)	0.0-55.0
Cummulative COVID-19 cases	53	820.0 (295.0-2216.0)	0.0- 37525.0
Cummulative COVID-19 cases per million	53	63.0 (17.0-243.0)	0.0-3987.0
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	52	5.3 (3.9-6.9)	2.8-13.4
BCG immunization coverage among 1-year-olds (%)	52	91.5 (84.0-96.5)	52.0-99.0
Early initiation of breastfeeding (%)	46	51.4 (35.7-65.3)	23.0-93.1
Life expectancy at birth (years)	52	63.2 (59.8-66.1)	52.9-76.4
Healthy life expectancy (HALE) at birth (years)	52	55.7 (52.3-57.9)	44.9-66.3
Medical doctors (per 10 000 population)	51	1.6 (0.8-4.0)	0.1-25.3
Nursing and midwifery personnel (per 10 000 population)	51	8.8 (4.4-15.5)	0.1-80.8
Hospital beds (per 10 000 population)	51	10.0 (5.0-18.0)	1.0-36.0
UHC index of service coverage (SCI)	52	0.5 (0.4-0.5)	0.3-0.8
Prevalence of insufficient physical activity among adults aged 18+ years	45	22.1 (15.4-28.0)	5.5-41.3
Prevalence of overweight among adults	51	28.9 (26.2-36.8)	20.9-63.5
Incidence of tuberculosis (per 100 000 population per year)	52	175.0 (79.0-303.0)	12.0-611.0
Prevalence of HIV among adults aged 15 to 49 (%)	50	1.6 (0.7-4.6)	0.1-27.3

Table 3: Risk factors for COVID-19 deaths and cases per million in Africa

Variables	Univariate		Multivariate	
	Beta (Std. Error)	p-value	Beta (Std. Error)	p-value
a) Sub-Saharan Africa				
Risk factors for deaths				
BCG immunization coverage among 1-year-olds (%)	-.0302 (0.0189)	0.1106	-.0293 (0.0191)	0.1242
Nursing and midwifery personnel (per 10 000 population)	-.0324 (0.0343)	0.3467	-.0426 (0.0178)	**0.0171**
UHC index of service coverage (SCI)	4.8486 (1.7709)	0.0062	4.7049 (2.3268)	**0.0432**
Prevalence of insufficient physical activity among adults aged 18+ years	0.1201 (0.0243)	<.0001	0.0830 (0.0333)	**0.0127**
Risk factors for cases per million				
Early initiation of breastfeeding (%)	-.0534 (0.0143)	0.0002	-.0563 (0.0136)	**<.0001**
Healthy life expectancy (HALE) at birth (years)	0.0917 (0.0410)	0.0251	0.0870 (0.0415)	**0.0373**
Prevalence of overweight among adults	0.0958 (0.0390)	0.0140	0.0417 (0.0340)	0.2214
b) All the African countries				
Risk factors for deaths (all countries)				
Early initiation of breastfeeding (%)	-.0437 (0.0183)	0.0205	-.0514 (0.0171)	**0.0027**
Healthy life expectancy (HALE) at birth (years)	0.0865 (0.0465)	0.0626	0.1059 (0.0483)	**0.0285**
Risk factors for cases per million (all countries)				
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	-.1913 (0.0896)	0.0328	-.1739 (0.0845)	**0.0397**
Early initiation of breastfeeding (%)	-.0476 (0.0169)	0.0049	-.0460 (0.0167)	**0.0061**

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Submitted Manuscript
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	The title of the manuscript includes the study design and other commonly used terms.
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	The abstract is structured and provides a comprehensive and balanced summary of the manuscript and the key findings.
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Paragraph 1 and 2 of the introduction
Objectives	3	State specific objectives, including any prespecified hypotheses	Paragraph 3 of the introduction
Methods			
Study design	4	Present key elements of study design early in the paper	Paragraph 1 of Methodology
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Paragraph 1 of Methodology on setting being Africa and the period being year 2020. Other setting parameters listed here are not applicable.
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Paragraph 1 methods clarifies that only one eligibility was used i.e being a country in Africa.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	All the variables used in the study are clearly defined. See Table 1 and definition of variables under the Methodology section.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Paragraph 1 of statistical methods.
Bias	9	Describe any efforts to address potential sources of bias	Statistical methodology paragraph 4. Multiple imputation was used to minimise potential bias due to missing data.
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	This is done in the statistical methodology section.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Yes all statistical methods used are described in the statistical methodology section
		(*b*) Describe any methods used to examine	N/A

		subgroups and interactions	
		(*c*) Explain how missing data were addressed	Statistical methods paragraph 5.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	Sensitivity analyses looking at sub-Saharan Africa and the whole of Africa is presented in Statistical Methodology Paragraph 6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	(a) is not applicable. Descriptive characteristics of countries is presented in Table 2.
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	These are presented in Table 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Yes this are done for univariate (unadjusted) and multivariate (adjusted) regressions (See Table 3)
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Yes this is done. A separate analysis for sub Saharan Africa was done and findings presented.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion section paragraph 1 presents a summary of key results.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and	The limitations are presented in the second last paragraph of the discussion section.

		magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	This is presented in the last paragraph of the discussion section.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Yes
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	A statement is provided on source of funding

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.

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Title: Factors associated with COVID-19 infections and mortality in Africa: A cross-sectional study using publicly available data

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Abstract

Introduction

The current COVID-19 pandemic is a global threat. This elicits questions on the level of preparedness and capacity of health systems to respond to emergencies relative to other parts of the world.

Methods

This cross-sectional study uses publicly available core health data for 53 African countries, to determine risk factors for cumulative COVID-19 deaths and cases per million in all countries in the continent. Descriptive statistics were determined for the indicators and a negative binomial regression was used for modelling the risk factors.

Results

In Sub-Saharan Africa, an increase in the number of nursing and midwifery personnel decreased the risk of COVID-19 deaths ($p=0.0178$) while a unit increase in universal health care (UHC) index of service coverage and prevalence of insufficient physical activity among adults increased the risk of COVID-19 deaths ($p=0.0432$ and $p=0.0127$). An increase in the proportion of infants initiating breastfeeding reduced the number of cases per million ($p<0.0001$) while an increase in higher healthy life expectancy at birth increased the number of cases per million ($p=0.0340$).

Conclusion

Despite its limited resources, Africa's preparedness and response to the COVID-19 pandemic can be improved by identifying and addressing *specific* gaps in the funding of health services delivery. These gaps impact negatively on service delivery in Africa which requires more nursing personnel and increased UHC coverage to mitigate the effects of COVID-19.

Article Summary

a. Strengths of the study:
   i. Innovative use of credible publicly available data which can easily be accessed and verified
   ii. Use of multiple imputation technique to address missing observations in the different variables.
   iii. Use of robust negative binomial regression analysis method which allows for modeling of over-dispersion in the data.

b. Limitations of the study:
   i. Extracted data had missing observations which necessitated excluding some variables.
   ii. The methods used to impute for missing data may have overestimated the variance

Introduction

In January 2020, the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) popularly referred to as COVID-19 was identified as the cause of unknown pneumonia in Wuhan, China. Two months later, the World Health Organisation (WHO) classified COVID-19 as a pandemic. COVID-19 is a global health threat. Since March 2020, there has been a rapid increase in the number of cases globally. Globally, as of 30th August 2020, there have been 24,822,800 confirmed cases of COVID-19, including 838,360 deaths, reported to WHO. [1 2] In a bid to stop the virus from spreading, there has been a global restriction on several activities including travelling.[3 4] The economic impact of a global shutdown and pressure on frail health systems of many countries across the world presents great uncertainty for the remaining half of the year and the immediate future.

The United States of America, Brazil, the United Kingdom and countries in Western Europe notably Italy, Spain and France account for the highest number of COVID-19 cases and mortality.[2] With the possible exception of Brazil, these countries have advanced health systems, reliable epidemic surveillance and response systems and have been able to mobilize resources with which to respond. However, due to the sudden increase in demand for health personnel, test kits, emergency care equipment and personal protective equipment, the health systems of all affected countries have been put under significant strain. With varying efficacy, the affected countries have increased hospital facilities for critical cases, increased the daily number of tests to identify positive cases and increased provision of personal protective equipment (PPE) for health personnel. [4 5]

At present, in comparison to the United States of America (USA), and Europe, Africa has a lower number of cases and lower daily increase in infection. While this may seem an advantage, the WHO continues to express concern about the impact COVID-19 may have on Africa. This is because, from the perspective of capacity, African countries are in a parlous situation relative to Europe, North America and some parts of Asia. The health systems of many African countries have limited ability to roll out widespread community screening and testing, few health personnel, and limited emergency facilities to manage critically ill COVID-19 patients.[6] The easing of restrictions on social and economic activities is likely to lead to a second wave of cases of COVID-19 in African countries. So with the best will and effort, African countries cannot use the same methodology to respond and contain the pandemic to the level of the developed countries that have performed badly, let alone to that of those that have performed well. If they are to use their limited capacity efficiently, it is imperative African countries clearly identify factors that will support that objective and institute effective evidence-based approaches to managing COVID-19. Accordingly, in a bid to support focus on efficient capacity development, this study analyzes the relationship between health indicators and COVID-19 deaths and cases in African countries. While the indicators were drawn from different thematic areas, our analysis was largely data driven. We conducted analysis for sub-Saharan African (SSA) countries - the standard multilateral institutions data classification of Africa and also for all the countries on the

continent including those north of the Sahara, usually classified with the Middle East region. We present our analysis by SSA countries due to their higher burden of disease and all of Africa.

Methodology

This is a cross-sectional study of the most recent 2020 data for African countries extracted from the World Health Organisation Global Health Observatory Repository.[7] Before extraction, the research team reviewed available indicators in the 2018 Global Reference List of 100 Core Health Indicators (plus health-related SDGs) [8] and listed different indicators by thematic areas. These indicators directly or indirectly describe the potential ability of a country's health system to respond to the health needs of the population and may further determine the extent available services can be expanded to accommodate emergencies. Data on confirmed cases of coronavirus and deaths were obtained from the Worldometer Coronavirus Live Update.[9]

Definition of variables

BCG immunization coverage among 1-year olds (%): BCG immunization coverage among 1-year olds (%).[10]

Nursing and midwifery personnel (per 10 000 population): It is the density of nurses and midwifery personnel per 10 000 people.[10]

UHC index of service coverage: Coverage of essential health services such as reproductive, maternal, newborn and child health amongst others.[10]

Prevalence of insufficient physical activity among adults aged 18+ years: Insufficient physical activity was defined as adults not meeting the WHO recommendations on physical activity for health i.e, at least 150 min of moderate-intensity, or 75 min of vigorous-intensity physical activity per week, or any equivalent combination of the two.[11]

Early initiation of breastfeeding (%): Initiation of breastfeeding within the first hour of birth and exclusively breastfed for the first six months of life.[12]

Healthy life expectancy at birth (years): This is a life expectancy estimate that applies disability weights to health states to compute the equivalent number of years of good health that a new born can expect.[13]

Life expectancy at birth: This reflects the overall mortality level of a population. It summarizes the mortality pattern that prevails across all age groups - children and adolescents, adults and the elderly.[14]

Prevalence of overweight among adults: Adults with a body mass index ≥ 30.

Current health expenditure (CHE) as a percentage of gross domestic product (GDP): This indicates the level of resources channelled to health relative to other uses.[10]

Statistical methodology

Data for 32 indicators (or variables) from 12 thematic areas were extracted from the 2018 Global Reference List of 100 Core Health Indicators (Table 1). The 12 thematic areas are Mortality by Age and Sex, Mortality by Cause, Morbidity, Nutrition, Environmental Risk Factors, Non-Communicable Diseases, Immunization, Essential

health services, Utilization and access, Health workforce, Health Information and Health financing.

Data were extracted in .xls format for each variable and imported into STATA 15.0 software (StataCorp LLC College Station, TX). For each variable, the most recent data for all countries included in the study were retained with the corresponding year and country name in .dta format. The different variables were merged using the country name as the unique identifier to obtain the final data set used for the analysis. The countries were further categorized into their assigned WHO region and World Bank income group except Somalia that had missing data.

All data on health indicators were continuous and were analysed descriptively using median, interquartile range (IQR) and minimum and maximum values.

Of the 53 countries included in the analyses, there were varying proportions of < 10% missing data. To address this, we assumed a missing at random mechanism and applied a multiple imputation technique with ten imputations and summarised the results across all the datasets.[15] The fit of the multiple imputation was evaluated using variance information measures including relative efficiency.

The process of selection of variables for analysis was as follows. Firstly, the team reviewed all the core publicly available health indicators. Then the plausibility of the explanatory power of these variables in the context of this study was subjected to various statistical approaches. These include the use of univariate and multivariate regression selection procedures. This approach enabled the identification of the final variables.

Due to its flexibility in allowing for overdispersion, risk factors for cumulative COVID-19 deaths and cases per million were fitted using the negative binomial regression. Both univariate and multivariate regression models were fitted. In the multivariate model, a full model including all the variables was fitted and the final model determined using the backward selection procedure. Regression models were fitted for sub-Saharan Africa followed by a sensitivity analyses including all the countries in the continent. Model fit was assessed using the ratio of the deviance, scaled deviance, Pearson Chi-square and scaled Pearson Chi-square divided by the degrees of freedom. Additionally, we also assessed model fit using the cumulative sum of residual plots with 10 000 replications. Deaths and cases per million were those reported in the Worldometer as of 29th May 2020.

All statistical analyses were conducted using SAS Enterprise Guide 7.15 (SAS Institute Inc., NC, USA).

Results

Characteristics

A total of 53 countries from Africa were included in this analysis (Table 2). The median number of cumulative COVID-19 deaths across the African continent was 12

(IQR: 3-49), cumulative deaths per million (2, IQR:0.2-6.0), cumulative COVID-19 cases [820, IQR: 295-2216], cumulative cases per million (63, IQR: 17.0-243.0), current health expenditure was 5.3 (IQR: 3.9-6.9) and BCG immunisation coverage in 1-year olds was 91.5% (IQR: 84.0-96.5). The median life expectancy was 63.2 years (IQR: 59.8-66.1), healthy life expectancy 55.7 years (IQR: 52.3-57.9), medical doctors per 10 000 population was 1.6 (IQR: 0.8-4.0), nursing and midwifery personnel per 10 000 was 8.8 (IQR: 4.4-15.5) and universal health care (UHC) index of service coverage 0.5 (IQR: 0.4-0.5).

Risk factors for sub-Saharan Africa

Cumulative COVID-19 deaths

In the multivariate regression, modelling risk factors for COVID-19 deaths in sub-Saharan Africa and controlling for BCG immunization coverage, a unit increase in the number of nursing and midwifery personnel decreased the risk of death by 0.0426 (p=0.0178) whereas a unit increase in the UHC index of service coverage and prevalence of insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 deaths by 4.7049 (p=0.0432) and 0.0830 (p=0.0127) respectively (Table 3).

Cumulative Cases per Million

A unit increase in the proportion of infants initiating breastfeeding reduces the number of cases per million by 0.0563 (p<0.0001) whereas an increase in higher healthy life expectancy at birth increases the number of COVID-19 cases per million by 0.0417 (p=0.0340).

Risk factors for all the African countries

Cumulative COVID-19 deaths

Early initiation of breastfeeding (Beta= -0.0514, p-value=0.0027) was associated with a lower risk of death whereas increasing healthy life expectancy at birth was associated with a higher risk of death (Beta=0.1059, p-value=0.0285).

Cumulative cases per million

An increase in the current health expenditure as a percentage of GDP (Beta=-0.1739, p-value=0.0397) and the percentage initiated early on breastfeeding (Beta=-0.0460, p-value=0.0061) was associated with a decrease in cases of COVID-19 per million (Table 3).

In the multiple imputation estimations, the relative efficiency of variables where imputation was conducted ranged from 95% to 99% whereas the scaled deviance values for the regression models were within the acceptable range.

Discussion

This study considers the factors associated with COVID-19 deaths and infection cases per million from 53 of 54 African countries. In summary, building health capacity by

increasing the number of nursing and midwifery personnel will reduce COVID-19 deaths in sub-Saharan Africa. However, we also found that higher UHC index of service coverage and prevalence of insufficient physical activity in adults ≥ 18 years increases fatalities. Additionally, having a population with a high proportion of people where breastfeeding had been initiated early, provided protection. A higher healthy life expectancy increased the risk of cases. When evaluating all the African countries, the initiation of early breastfeeding was protective against death whereas higher healthy life expectancy increased the risk of death. We also find that an increase in current health expenditure levels provide additional protection against COVID-19 infections.

Delving deeper into our results, the finding that an increase in the number of nursing and midwifery personnel reduced the risk of COVID-19 related mortality in sub-Saharan Africa echo findings from other parts of the world where the benefits of preparedness and available capacity has been shown to confer benefits in the management and care of patients.[16 17] Where capacity shortages exist in the health sector, there is potential for poor outcomes in the management and care of COVID-19 patients. Major gaps still exist in the implementation of the WHO International Health Regulations, notably increasing capacity of hospitals and appropriate injection of financial resources.[17] The results confirm the point made earlier that unlike the other COVID-19 affected parts of the world, Africa has less capacity to handle a major outbreak of COVID-19. Therefore, African governments need to strengthen the overall health care systems and in doing so, specific focus needs to be placed on enhancing human resource capacity such as nurses, medical doctors and laboratory personnel.

Our findings also illustrate that a higher UHC index of service coverage increases the risk of fatalities. While counter-intuitive, this may be driven by the countries in sub-Saharan Africa with the largest economies that have also had the largest number of cases and mortality: South Africa and Nigeria. A large number of people from these two countries travel internationally, in particular to Europe and it is likely that they have contracted the disease there and have imported it back into their countries.[18] To assess the robustness of this finding, we conducted a sensitivity analysis by removing the data on South Africa and Nigeria and re-estimated the model. No major differences relative to the first regression were observed suggesting that importation of infections similarly occurred in other sub-Saharan African countries.

Additionally, that cohort of the population that travels internationally is generally able to afford COVID-19 test kits and conduct more tests. Testing is a critical requirement for effective management of COVID-19. From a statistical perspective, testing identifies cases which may be managed before getting severe resulting in deaths. This increases the number of observations on deaths. This view is similar to that reported in a previous paper on the vulnerability of African countries to COVID-19 and their preparedness to mitigate.[18]

More intuitively, we find that insufficient physical activity among adults aged 18+ years increased the risk of COVID-19 mortality. It is well documented in the literature that the lack of physical activity increases the risk of obesity.[19] Recent publications on

COVID-19 related mortality, have shown that obesity elevates the risk of mortality.[20 21] Physical inactivity has long been recognized as a risk factor for non-communicable diseases which is a known cause of mortality globally.[22 23] Early studies since the onset of the COVID-19 outbreak in China indicated elderly patients and those with co-morbidities particularly diabetes, hypertension and chronic respiratory diseases were at increased risk of mortality from COVID-19.[24 25] Therefore, the finding of insufficient physical activity as a risk factor for death from our study is consistent with earlier studies (1).[23] Similarly, immunization has proved effective in prevention of different types of infectious diseases globally while breastfeeding provides babies with essential nutrients and antibodies to help prevent infections early in life. Hence, establishment of expanded program on immunization (EPI) and programs to encourage breastfeeding globally. Thus we postulate that the population of Africans aged 18+ years who do not undertake sufficient physical activity may be similarly at high risk of mortality.

We also found that where a large population is exposed to early initiation of breastfeeding, there was protection against COVID-19 infection. Research on the long-term benefits of breastfeeding is growing and recent evidence suggests a protective effect against some chronic diseases in adulthood.[26 27] It may be that this protective effect extends to non-severe cases of COVID-19.

Further, in sub-Saharan Africa and all the African countries combined, higher healthy life expectancy (life expectancy that accounts for disabilities) in this study was associated with a higher risk of COVID-19 infection. Our findings are in tandem with previously published work on risk factors for COVID-19 infection from around the world that have shown older people are at higher risk for COVID-19 infection. Being older is associated with lower immunity and inflammatory reactions and a higher risk of comorbidities such as diabetes and hypertension amongst others. Such factors predispose older cohorts of the population to COVID-19 infection.

This study is not without limitations. The data used was sourced from publicly available repositories and therefore we had no control in sampling, study design and data collection processes. The study we conducted is cross-sectional and therefore cannot deduce causality. Since COVID-19 statistics are updated on a daily basis, the findings we report may vary with updated data. Despite these challenges, we applied robust statistical analysis methods to alleviate potential biases.

In conclusion, our study findings showed a relationship between COVID-19 cases and deaths with health capacity, breast feeding, life expectancy (as a proxy for age) and healthcare funding. Timely identification of the key evidence-based factors that might mitigate COVID-19 infections and deaths in Africa is pertinent for better management of the current and future pandemics. This may include investing in healthcare capacity building, infrastructure, disease surveillance, public health laboratories and all other aspects that relate to health as elucidated in the WHO International Health Regulations.[28]

Patient and public involvement
This study utilised publicly available health indicators and aggregated COVID-19 cases and deaths. No patients were involved.

Funding
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Contributorship Statement
CO developed the initial research concept, developing the hypothesis and methodology. VW did the data extraction and merging of the different data sets. KO participated in developing the hypothesis and conducted the data analysis. All the authors participated in interpreting the results and writing the manuscript.

Data sharing statement
Data used for analysis is available in the Dryad data repository reference DOI: 10.5061/dryad.cnp5hqc2r.

Ethics, Funding and Data Sharing
1. This study did not require ethical clearance as the data used for analysis is publicly available. Precautions were, however, adopted to document steps taken during data extraction, cleaning and analysis.
2. This manuscript did not receive funding from any organization and the authors declare no competing interest.

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Table 1: Summary of thematic areas of health indicators

Thematic Area	Indicators used
Mortality by age and sex	Life expectancy and healthy life expectancy at birth (years)
	Adult mortality rate between 15 and 60 years of age (Adult mortality rate (probability of dying between 15 and 60 years per 1000 population))
	Under-five mortality rate (per 1000 live births)
	Infant mortality rate (per 1000 live births)
	Neonatal mortality rate (per 1000 live births)
Mortality by cause	Maternal mortality ratio (Maternal mortality ratio (per 100 000 live births))
	TB mortality rate (per 100 000 population)
	AIDS-related mortality rate
	Mortality from unsafe water, unsafe sanitation and lack of hygiene
Morbidity	HIV prevalence rate (per 1000 population)
	HIV incidence rate (per 1000 population)
	TB incidence rate (per 100 000 population)
Nutrition	Exclusive breastfeeding rate 0–5 months of age (%)
	Early initiation of breastfeeding (%)
Environmental risk factors	Population using safely managed drinking-water services (%)
	Population using safely managed sanitation services (Also: population with handwashing facility with soap and water) (%)
	Air pollution level in cities (ug/m3)
Non-communicable diseases	Tobacco use among persons aged 15+ years [SDG 3.a.1] (Also: adolescents) (%)
	Raised blood pressure among adults (18+ %)
	Overweight and obesity in adults (Also: school-age children and adolescents) (%)
	Raised blood glucose/diabetes among adults (%)
	Insufficient physical activity in adults (Also: adolescents) (%)
Immunization	Immunization coverage rate by vaccine for each vaccine in the national schedule (%)
Essential health services	Coverage of essential health services (%)
Utilization and access	Health facility density and distribution (Also: access to emergency surgery) (per 10 000 population)
	Hospital bed density (per 10 000 population)
	Access to a core set of relevant essential medicines (%)
Health workforce	Health worker density and distribution (per 10 000 population)
Health information*	Completeness of reporting by facilities (Also: completeness and timeliness for notifiable diseases)
Health financing	Total current expenditure on health as % of gross domestic product (Also: total capital expenditure on health as % of current + capital expenditure on health)
	Public domestic sources of current spending on health as % of current health expenditure
	External source of current spending on health (% of current expenditure on health)

*Data not available

Table 2: Descriptive summary of key health system indicators for African countries

Variables	Number of countries	Median (IQR)	Minimum-Maximum
Cummulative COVID-19 deaths	53	12.0 (3.0-49.0)	0.0- 1088.0
Cummulative COVID-19 deaths per million	53	2.0 (0.2-6.0)	0.0-55.0
Cummulative COVID-19 cases	53	820.0 (295.0-2216.0)	0.0- 37525.0
Cummulative COVID-19 cases per million	53	63.0 (17.0-243.0)	0.0-3987.0
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	52	5.3 (3.9-6.9)	2.8-13.4
BCG immunization coverage among 1-year-olds (%)	52	91.5 (84.0-96.5)	52.0-99.0
Early initiation of breastfeeding (%)	46	51.4 (35.7-65.3)	23.0-93.1
Life expectancy at birth (years)	52	63.2 (59.8-66.1)	52.9-76.4
Healthy life expectancy (HALE) at birth (years)	52	55.7 (52.3-57.9)	44.9-66.3
Medical doctors (per 10 000 population)	51	1.6 (0.8-4.0)	0.1-25.3
Nursing and midwifery personnel (per 10 000 population)	51	8.8 (4.4-15.5)	0.1-80.8
Hospital beds (per 10 000 population)	51	10.0 (5.0-18.0)	1.0-36.0
UHC index of service coverage (SCI)	52	0.5 (0.4-0.5)	0.3-0.8
Prevalence of insufficient physical activity among adults aged 18+ years	45	22.1 (15.4-28.0)	5.5-41.3
Prevalence of overweight among adults	51	28.9 (26.2-36.8)	20.9-63.5
Incidence of tuberculosis (per 100 000 population per year)	52	175.0 (79.0-303.0)	12.0-611.0
Prevalence of HIV among adults aged 15 to 49 (%)	50	1.6 (0.7-4.6)	0.1-27.3

Table 3: Risk factors for COVID-19 deaths and cases per million in Africa

Variables	Univariate		Multivariate	
	Beta (Std. Error)	p-value	Beta (Std. Error)	p-value
a) Sub-Saharan Africa				
Risk factors for deaths				
BCG immunization coverage among 1-year-olds (%)	-.0302 (0.0189)	0.1106	-.0293 (0.0191)	0.1242
Nursing and midwifery personnel (per 10 000 population)	-.0324 (0.0343)	0.3467	-.0426 (0.0178)	**0.0171**
UHC index of service coverage (SCI)	4.8486 (1.7709)	0.0062	4.7049 (2.3268)	**0.0432**
Prevalence of insufficient physical activity among adults aged 18+ years	0.1201 (0.0243)	<.0001	0.0830 (0.0333)	**0.0127**
Risk factors for cases per million				
Early initiation of breastfeeding (%)	-.0534 (0.0143)	0.0002	-.0563 (0.0136)	**<.0001**
Healthy life expectancy (HALE) at birth (years)	0.0917 (0.0410)	0.0251	0.0870 (0.0415)	**0.0373**
Prevalence of overweight among adults	0.0958 (0.0390)	0.0140	0.0417 (0.0340)	0.2214
b) All the African countries				
Risk factors for deaths (all countries)				
Early initiation of breastfeeding (%)	-.0437 (0.0183)	0.0205	-.0514 (0.0171)	**0.0027**
Healthy life expectancy (HALE) at birth (years)	0.0865 (0.0465)	0.0626	0.1059 (0.0483)	**0.0285**
Risk factors for cases per million (all countries)				
Current health expenditure (CHE) as percentage of gross domestic product (GDP)	-.1913 (0.0896)	0.0328	-.1739 (0.0845)	**0.0397**
Early initiation of breastfeeding (%)	-.0476 (0.0169)	0.0049	-.0460 (0.0167)	**0.0061**

STROBE Statement—Checklist of items that should be included in reports of ***cross-sectional studies***

	Item No	Recommendation	Submitted Manuscript
Title and abstract	1	(*a*) Indicate the study's design with a commonly used term in the title or the abstract	The title of the manuscript includes the study design and other commonly used terms.
		(*b*) Provide in the abstract an informative and balanced summary of what was done and what was found	The abstract is structured and provides a comprehensive and balanced summary of the manuscript and the key findings.
Introduction			
Background/rationale	2	Explain the scientific background and rationale for the investigation being reported	Paragraph 1 and 2 of the introduction
Objectives	3	State specific objectives, including any prespecified hypotheses	Paragraph 3 of the introduction
Methods			
Study design	4	Present key elements of study design early in the paper	Paragraph 1 of Methodology
Setting	5	Describe the setting, locations, and relevant dates, including periods of recruitment, exposure, follow-up, and data collection	Paragraph 1 of Methodology on setting being Africa and the period being year 2020. Other setting parameters listed here are not applicable.
Participants	6	(*a*) Give the eligibility criteria, and the sources and methods of selection of participants	Paragraph 1 methods clarifies that only one eligibility was used i.e being a country in Africa.
Variables	7	Clearly define all outcomes, exposures, predictors, potential confounders, and effect modifiers. Give diagnostic criteria, if applicable	All the variables used in the study are clearly defined. See Table 1 and definition of variables under the Methodology section.
Data sources/ measurement	8*	For each variable of interest, give sources of data and details of methods of assessment (measurement). Describe comparability of assessment methods if there is more than one group	Paragraph 1 of statistical methods.
Bias	9	Describe any efforts to address potential sources of bias	Statistical methodology paragraph 4. Multiple imputation was used to minimise potential bias due to missing data.
Study size	10	Explain how the study size was arrived at	N/A
Quantitative variables	11	Explain how quantitative variables were handled in the analyses. If applicable, describe which groupings were chosen and why	This is done in the statistical methodology section.
Statistical methods	12	(*a*) Describe all statistical methods, including those used to control for confounding	Yes all statistical methods used are described in the statistical methodology section
		(*b*) Describe any methods used to examine	N/A

		subgroups and interactions	
		(*c*) Explain how missing data were addressed	Statistical methods paragraph 5.
		(*d*) If applicable, describe analytical methods taking account of sampling strategy	NA
		(*e*) Describe any sensitivity analyses	Sensitivity analyses looking at sub-Saharan Africa and the whole of Africa is presented in Statistical Methodology Paragraph 6
Results			
Participants	13*	(a) Report numbers of individuals at each stage of study—eg numbers potentially eligible, examined for eligibility, confirmed eligible, included in the study, completing follow-up, and analysed	NA
		(b) Give reasons for non-participation at each stage	NA
		(c) Consider use of a flow diagram	NA
Descriptive data	14*	(a) Give characteristics of study participants (eg demographic, clinical, social) and information on exposures and potential confounders	(a) is not applicable. Descriptive characteristics of countries is presented in Table 2.
		(b) Indicate number of participants with missing data for each variable of interest	NA
Outcome data	15*	Report numbers of outcome events or summary measures	These are presented in Table 2
Main results	16	(*a*) Give unadjusted estimates and, if applicable, confounder-adjusted estimates and their precision (eg, 95% confidence interval). Make clear which confounders were adjusted for and why they were included	Yes this are done for univariate (unadjusted) and multivariate (adjusted) regressions (See Table 3)
		(*b*) Report category boundaries when continuous variables were categorized	NA
		(*c*) If relevant, consider translating estimates of relative risk into absolute risk for a meaningful time period	NA
Other analyses	17	Report other analyses done—eg analyses of subgroups and interactions, and sensitivity analyses	Yes this is done. A separate analysis for sub Saharan Africa was done and findings presented.
Discussion			
Key results	18	Summarise key results with reference to study objectives	Discussion section paragraph 1 presents a summary of key results.
Limitations	19	Discuss limitations of the study, taking into account sources of potential bias or imprecision. Discuss both direction and	The limitations are presented in the second last paragraph of the discussion section.

		magnitude of any potential bias	
Interpretation	20	Give a cautious overall interpretation of results considering objectives, limitations, multiplicity of analyses, results from similar studies, and other relevant evidence	This is presented in the last paragraph of the discussion section.
Generalisability	21	Discuss the generalisability (external validity) of the study results	Yes
Other information			
Funding	22	Give the source of funding and the role of the funders for the present study and, if applicable, for the original study on which the present article is based	A statement is provided on source of funding

*Give information separately for exposed and unexposed groups.

Note: An Explanation and Elaboration article discusses each checklist item and gives methodological background and published examples of transparent reporting. The STROBE checklist is best used in conjunction with this article (freely available on the Web sites of PLoS Medicine at http://www.plosmedicine.org/, Annals of Internal Medicine at http://www.annals.org/, and Epidemiology at http://www.epidem.com/). Information on the STROBE Initiative is available at www.strobe-statement.org.