Evaluating Sub-Saharan Africa's COVID-19 Research Contribution: A Preliminary bibliometric Analysis

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Abstract:

The response to the ongoing COVID-19 pandemic in the science community is unprecedented as indicated by the high number of research publications. Deeper insight into COVID-19 research at regional, and national levels through bibliometric research has revealed different levels of research evolution, depth, contribution, and collaboration patterns. Such reliable and evidence-based information is important for health research planning and policy making. This study aims at providing some evidence-based insight into Sub-Saharan Africa's preliminary COVID-19 research by evaluating its research contributions, patterns of collaboration, and funding sources. COVID-19 publication data from all the 41 Sub-Saharan African countries was collected from Scopus for analysis. Results show that Sub-Saharan Africa contributed about two percent to global COVID-19 research. South Africa contributed 50.95% of all the COVID-19 publications from Sub-Saharan Africa while USA (28.48%) and the UK (24.47%), the top two external contributors, collaborated with Sub-Saharan African countries three times more than other countries. Collaborative papers between Sub-Saharan African countries - without contributions from outside the region- made up less than five percent of the sample, whereas over 50% of the papers were written in collaboration with researchers from outside the region. Organizations based in USA, UK, and EU funded more than 60% of all the COVID-19 research from Sub-Saharan Africa. More than 60% of all the funding from Sub-Saharan African countries came from South African organizations. This study provides evidence that pan-African COVID-19 research collaboration is low, perhaps due to poor funding and institutional support within Africa. There is a need to forge stronger pan-African research collaboration networks, through funding from Africa's national and regional government organizations, with the specific objective of meeting COVID-19 healthcare needs of Africans.

Keywords: COVID-19, Sub-Saharan Africa, research collaboration, international collaboration, research funding, bibliometric analysis

1. Introduction

One of the applications of bibliometrics in public health emergencies is the analysis of research communications to reveal geographic contributions and cooperation in specific timeframes. Quantitative science analyses can also reveal the evolution of research trends that are useful in health research planning (Zhang et al., 2020). For example, Zhao et al., (2015) worked on Ebola Virus Disease (EVD) to create an understanding on how EVD research evolved over the years. Other bibliometric studies conducted collaboration analyses to understand the research contributions of institutions and countries on infectious diseases such as EVD (Cruz-Calderón et al., 2015; Pouris & Ho, 2016; Quarcoo et al., 2015; Yi et al., 2016) Severe Acute Respiratory Syndrome (SARS) (Kostoff & Morse, 2011; Sweileh, 2017)), Zika Virus (ZIKV) (Delwiche, 2018), Middle East Respiratory Syndrome (MERS) (Wang et al., 2016) and Lassa fever (Sweileh, 2017).

COVID-19, a once-in-a-generation health emergency of global magnitude, has also received considerably strong attention in the quantitative science community. Bibliometric studies revealed that the response to the COVID-19 pandemic in the scientific community has no precedence (Haghani & Bliemer, 2020; Kambhampati et al., 2020). Unprecedented levels of global collaboration were detected in bibliographic data analysis only three months after the onset of the COVID-19 pandemic (Gong et al., 2020; Kambhampati et al., 2020). According to Gong et al. (2020), within two months of the outbreak of COVID-19, a knowledge scape had been formed that included etiology, epidemiology, diagnosis, treatment, prevention and control to the level that knowledge gaps were adequately identified; an indication of the unprecedented depth of research on the COVID-19 pandemic (Gong et al., 2020). Quantitative analyses of COVID-19 have also helped to understand the peculiarities of COVID-19 research and to visualize evolutionary trends that could help predict research directions and policy development.

There are indications that most of the COVID-19 research that reported or measured the response by Africa has been anecdotal. This is a global trend as analysis of COVID-19 research revealed that less than 50% of the global COVID-19 research output in the first seven months could be classified as research articles (Haghani & Bliemer, 2020). While the importance of anecdotal reporting in research, especially on subjects with more ‘unknowns’ than ‘knowns’ such as the COVID-19 pandemic, cannot be discounted, evidence-based and data-driven reporting is much needed for objectivity. Unfortunately, literature search shows that there are hardly evidence-based, pan-African studies on COVID-19 research. One notable data-driven pan-African COVID-19 studies is Asubiaro et al., (2020) which analyzed Anglophone African countries’ uses of social media for disseminating COVID-19 information to their citizens by analyzing national health ministries and departments social media data.

This study contributes to research on the pan-African scientific outlook. Secondly, this study provides insights into Africa’s scientific response to the ongoing COVID-19 pandemic by using evidence-based and data-driven methods of inquiry to create analytic content on Sub-Saharan

Africa's research contributions. While many bibliometric studies have been done on global, regional and national COVID-19 research outputs (Fan et al., 2020; Shamsi et al., 2020; Zhang et al., 2020) and disciplines (Aristovnik et al., 2020), there are no bibliometric studies on pan-African or African countries' COVID-19 research. This study fills a research gap in literature that is particularly important for strategic planning by the research community and stakeholders in Sub-Saharan Africa. The specific objectives of this study are to:

1. present a collaboration pattern analysis of Sub-Saharan Africa's COVID-19 research,
2. investigate how countries within and outside Sub-Saharan Africa contribute to Sub-Saharan Africa's COVID-19 research, and
3. investigate the sources of funding for COVID-19 research in Sub-Saharan Africa.

2. Methodology

Global and Sub-Saharan Africa's COVID-19 research records were retrieved from Elsevier's Scopus database. The search of Scopus was done on the 1st of September 2020 to capture publications from the first eight months of 2020. The search query was composed to retrieve publications on COVID-19 that were published by authors who are affiliated with institutions in Sub-Saharan Africa. The search query included the names of all the 41 countries in Sub-Saharan Africa. Variants of the Sub-Saharan African countries' names (e.g. Cameroun and Cameroon) were also included so that indexes with their variant names would be captured. All the variant names of COVID-19, as specified in peer-reviewed search strings of the Medical Library Association for bibliographic database retrieval of COVID-19 publications, were also included in the search query (LaLonde, 2020). The search query was repeated without country names to retrieve global COVID-19 scientific publications data. The search query for retrieving Sub-Saharan Africa's publication is as follows:

> *AFFILCOUNTRY ("South Africa" OR "Nigeria" OR "Angola" OR "Benin" OR "Burkina Faso" OR "Burundi" OR "Cameroon" OR "Cameroun" OR "Canary Islands" OR "Cape Verde" OR "Central African Republic" OR "Chad" OR "Comoros" OR "Congo" OR "Democratic Republic of Congo" OR "DR Congo" OR "Cote D'ivoire" OR "ivory coast" OR "Kenya" OR "Lesotho" OR "Liberia" OR "Madagascar" OR "Malawi" OR "Mali" OR "Mauritius" OR "Mozambique" OR "Mocambique" OR "Namibia" OR "Niger" OR "Principe" OR "Reunion" OR "Rwanda" OR "Sao Tome" OR "Senegal" OR "Seychelles" OR "Sierra Leone" OR "Somalia" OR "Sudan" OR "Swaziland" OR "Tanzania" OR "Togo" OR "Uganda" OR "Zaire" OR "Zambia" OR "Zimbabwe" OR "South Sudan") AND TITLE-ABS-KEY ("2019 novel coronavirus disease" OR "COVID19" OR "COVID-19 pandemic" OR "SARS-CoV-2 infection" OR "COVID-19 virus disease" OR "2019 novel coronavirus infection" OR "2019-nCoV infection" OR "coronavirus disease 2019" OR "coronavirus disease-19" OR "2019-nCoV disease" OR "COVID-19 virus infection" OR "severe acute respiratory syndrome coronavirus 2" OR "COVID-19" OR "COVID19" OR "COVID2019" OR "SARSCoV2" OR*

"SARS coronavirus 2" OR "2019-nCoV" OR "2019nCoV" OR "nCoV2019" OR "nCoV-2019" OR "Wuhan coronavirus" OR "Hubei coronavirus" OR "chin coronavirus")*

The resultant Sub-Saharan Africa's COVID-19 publication dataset was coded for collaboration analysis using the following categories: number of authors, number of institutions and countries of affiliation of author(s), names of institutions, and countries of affiliation. Five levels of collaboration were identified and coded: single author or no collaboration, institutional, national, Sub-Saharan African, and international collaborations. Single author papers were classified as "no collaboration" papers. Papers that were written by more than one author that are all affiliated to one institution were classified as *institutional collaboration.* Papers by multiple authors who were affiliated to multiple institutions, where all the institutions are located in one country were classified as *national collaboration.* Papers that were written by more than one author, who were affiliated to multiple institutions, where the institutions are located in multiple Sub-Saharan African countries and no author was affiliated with institutions outside Sub-Saharan Africa were classified as *Sub-Saharan African collaboration.* Papers that were written by multiple authors with multiple affiliated institutions, where the institutions are located in at least one country within and one country outside of Sub-Saharan Africa were classified as *international collaboration.*

Productivity of the countries in Sub-Saharan Africa to the COVID-19 research was measured as the number of publications from each country. Contributions of the ten most productive Sub-Saharan African countries to each others' COVID-19 research was analyzed to illuminate the depth of knowledge exchange between Sub-Saharan African countries. COVID-19 research contributions of the top ten countries outside the region, that collaborated with authors in the top ten most productive Sub-Saharan African countries were investigated to illuminate the contributions to Sub-Saharan Africa's COVID-19 research from other regions. Funding statements were also analyzed to understand the sources of funding for COVID-19 research. Comparisons in the number of publications that have been produced globally and from authors from Africa were made. Comparisons were also made between the proportion of publications in research areas and document types in the publications from global and African research outputs. The collaboration pattern was visualized using VOS viewer (van Eck & Waltman, 2017).

3. Results and Discussion

The search returned a total of 45,298 scientific publications records with 899 (1.98% of the global publication on COVID-19 research) from Sub-Saharan Africa. The contribution of Sub-Saharan Africa is small, comparing it to previous studies is difficult since they focused on the whole of Africa. For instance, Confraria & Godinho (2015) reported that the whole of Africa, including Sub-Saharan Africa, contributed 2.6% of the world's research in 2013. The result of the first comparison, which was made between the publications document types, are displayed in Table 1. The document types show a strong similarity between global and Sub-Saharan Africa's research output; articles constitute less than 50% of all document types. Letters, reviews, notes, and editorial materials are the other notable document types.

The second comparison was contributions by discipline, which also reveal similarities between the global and Sub-Saharan African responses: Medicine constituted about 50% of the publications from the globe and Sub-Saharan Africa, with other notable disciplines being Biochemistry, Genetics and Molecular Biology, Social Sciences, Immunology, and Microbiology. Details of the disciplinary comparison is found in Table SM1 of the attached supplementary document.

Table 1: Comparison of global and Sub-Saharan Africa's Document Types

	Global contribution		Sub-Saharan African contribution	
1	Article	49.79%	Article	47.83%
2	Letter	19.78%	Letter	16.24%
3	Review	10.69%	Note	13.01%
4	Note	8.91%	Review	12.68%
5	Editorial	8.46%	Editorial	7.56%
6	Short Survey	1.12%	Short Survey	1.33%
7	Erratum	0.63%	Data Paper	0.78%
8	Conference Paper	0.45%	Conference Paper	0.22%
9	Data Paper	0.12%	Erratum	0.22%
10	Book Chapter	0.04%	Book Chapter	0.11%
11	Conference Review	0.007%		
12	Retracted	0.002%		

3.1 Productivity and Collaboration Pattern

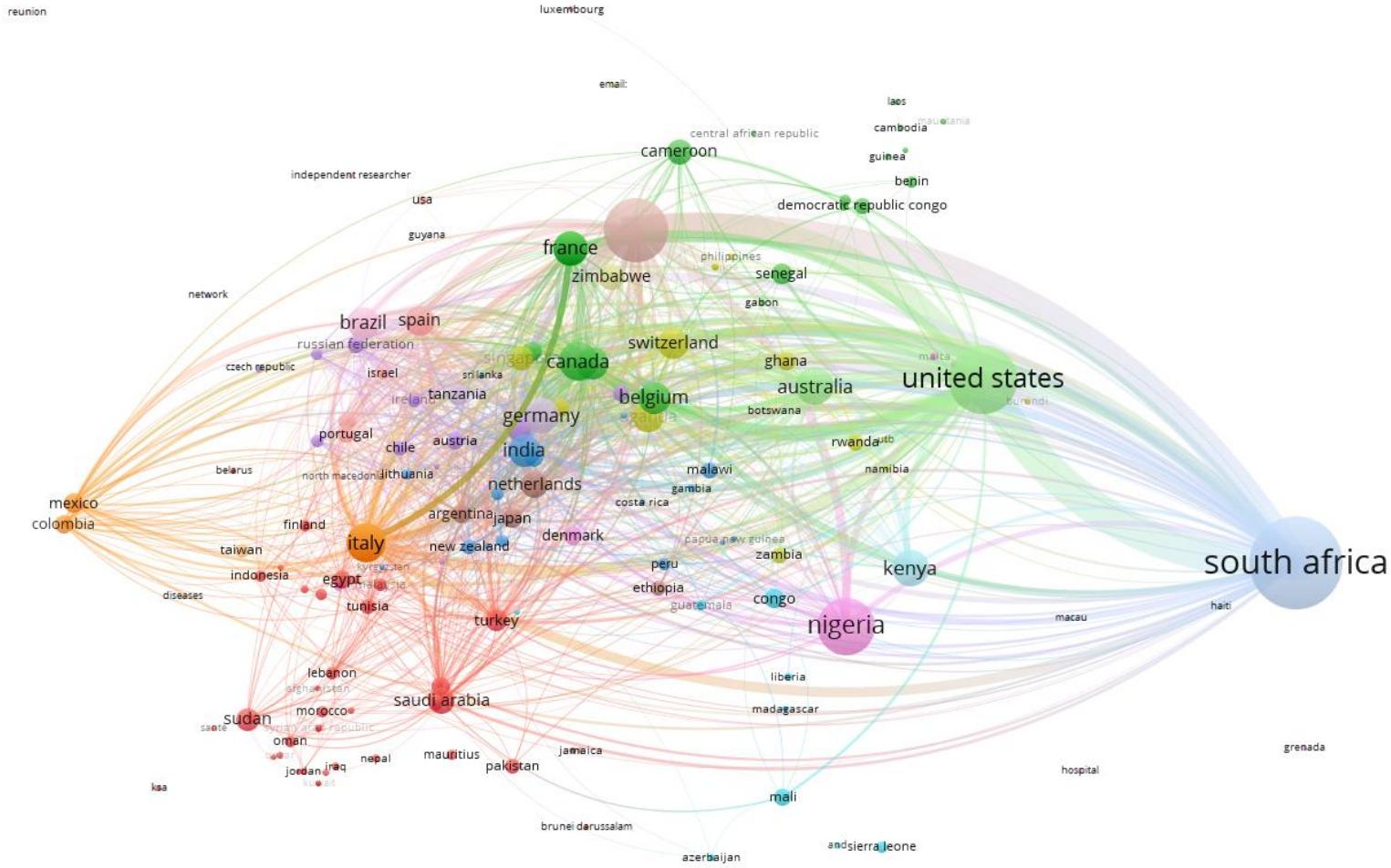
The results of the collaboration analysis (visualized in Fig. SM2) show that most (55.73%) of the publications are products of international collaboration; only 44.27% of the papers were authored without contribution from outside Sub-Saharan Africa. Publications with only Sub-Saharan African affiliation constituted 13.99% single author papers, 12.35% institutional collaborations, and 11.52% national collaborations. The least popular form of collaboration was Sub-Saharan African collaboration (4.94%).

The number of publications from the top twenty most productive Sub-Saharan countries and the number of publications in which countries from outside Sub-Saharan Africa contributed is presented on Table 2. The result shows that South Africa contributed to 50.95% of all the publications from the 41 Sub-Saharan African countries. Other substantial contributions are from Nigeria (19.58%), Kenya (8.23%), and Uganda (5.67%). Together, contributions from South Africa and Nigeria constitute about 70% of all the publications from Sub-Saharan Africa. The results also show that the United States of America (USA) (28.48%) and the United Kingdom (UK) (24.47%) collaborated with Sub-Saharan African countries on COVID-19 research on about 25% of all publications; each of these two countries collaborated with sub-Saharan Africa three times more than other countries. Other countries such as Canada (8.90%) Australia (8.57%), Italy (8.23%) and Germany (7.79%) also each collaborated on greater than 6% of the publications from Sub-Saharan Africa on COVID-19.

Table 2: Productivity of Sub-Saharan African Countries and contribution of countries outside Sub-Saharan Africa

Countries in Sub-Saharan Africa			Countries outside Sub-Saharan Africa		
Rank	Country name	Percentage contribution	rank	Country name	Percentage contribution
1	South Africa	50.95	1	United States	28.48
2	Nigeria	19.58	2	United Kingdom	24.47
3	Kenya	8.23	3	Canada	8.90
4	Uganda	5.67	4	Australia	8.57
5	Zimbabwe	4.12	5	Italy	8.23
6	Cameroun	4.00	6	Germany	7.79
7	Sudan	3.11	7	France	6.56
8	Senegal	2.78	8	China	6.34
9	Tanzania	2.56	9	India	6.34
10	Congo	2.34	10	Belgium	6.23
11	Ghana	2.22	11	Brazil	6.01
12	Mozambique	2.22	12	Switzerland	5.67
13	Mali	1.78	13	Spain	5.34
14	Democratic Republic Congo	1.67	14	Netherlands	4.45
15	Rwanda	1.56	15	Saudi Arabia	4.12
16	Zambia	1.56	16	Singapore	3.67
17	Malawi	1.45	17	Sweden	3.56
18	Ethiopia	1.33	18	Turkey	3.00
19	Benin	0.78	19	Hong Kong	2.45
20	Cote d'Ivoire	0.78	20	Japan	2.45

Figure 1: Collaboration network between Sub-Saharan African countries and other countries on COVID-19 research



3.2 Internal and External Contributions to SSA's COVID-19 Scientific Output

Results of the collaboration network of Sub-Saharan Africa countries and other countries that collaborated with them on COVID-19 is illustrated in Figure 1. Colour represents cluster, circle size represents volume of contribution, and line width represents the volume of collaboration between connected countries. Figure 1 shows the four biggest research nodes are South Africa, United States of America, the United Kingdom, and Nigeria.

To bring Figure 1 into perspective, collaboration between the ten most productive sub-Saharan African countries were further analyzed and presented on Table 3. Table 3 shows the contributions of Sub-Saharan African countries to each others' research through collaboration. The results show that only South Africa made more contributions to research in other SSA countries; collaborations were made with Zimbabwe (29.72%), Congo (23.89%), Kenya (22.97%), Cameroun (22.22%), and Senegal (20%). Contributions from South Africa seem widespread, and do not appear to be dependent on proximity and language. For instance, while Zimbabwe (29.72%), and Kenya (22.97%) are also English-speaking countries, Cameroun, Congo, and Senegal are not. Earlier studies have identified language as a determinant for collaboration between African countries (Asubiaro & Badmus, 2020). Similarly, while Zimbabwe is close to South Africa geographically, Cameroun and Congo are not. Uganda's contribution of 21.74% to Tanzania's COVID-19 research is also significant. Considering Kenya's contribution (15.69%) to Uganda's COVID-19 research, scientific cooperation between both Uganda and Kenya, and Uganda and Tanzania seems substantial. This collaboration could be explained by their cultural similarity and geographical proximity.

While South Africa was the most impactful on other Sub-Saharan African countries' COVID-19 research, Table 3 also shows that 53% of the countries' possible interaction was null. In other words, Sub-Saharan Africa did not contribute to each others' COVID-19 research at 53% of possible interactions between any pair of countries. In addition, some countries are scientifically isolated among Sub-Saharan African countries. For instance, each of Sudan and Congo collaborated with just one other Sub-Saharan African country. Table 3 also shows a trend: Sub-Saharan countries that produced fewer COVID-19 studies also collaborated with fewer countries in the region. This is consistent with Onyancha & Maluleka, (2011) which showed Sub-Saharan African countries did contribute insignificantly to each others' research.

To better clarify the collaboration of Sub-Saharan countries with other countries of the world, Table 4 was created. Table 4 shows the contributions of countries from other world regions to Sub-Saharan African countries' COVID-19 research. Comparison between results on Tables 3 and 4 show that the collaboration between the Sub-Saharan African countries and countries outside the region is greater and stronger than collaboration among countries within the region. For instance, none of the Sub-Saharan African countries collaborated with every other fellow country in the region, on the other hand, three countries from the region (South Africa, Nigeria, and Cameroun) collaborated with all the top contributing countries from outside the region. Furthermore, all the 10 most productive Sub-Saharan African countries collaborated with at least five of the top ten

collaborating countries from outside the region. Lastly, less than half of any two matched Sub-Saharan African countries in the sample resulted in at least a publication, whereas 77% of matching a Sub-Saharan African country and a country from outside the region produced at least a publication. This further shows that countries from outside the Sub-Saharan African region hold a greater influence on Sub-Saharan Africa's COVID-19 research than their closer neighbours do.

Table 3: Contribution of SSA countries to each other's COVID-19 Scientific Contribution

		Publication number	South Africa	Nigeria	Kenya	Uganda	Zimbabwe	Cameroun	Sudan	Senegal	Tanzania	Congo
1	South Africa	458	1									
2	Nigeria	176	24	1								
3	Kenya	74	17	5	1							
4	Uganda	51	7	5	8	1						
5	Zimbabwe	37	11	3	3	3	1					
6	Cameroun	36	8	0	3	4	0	1				
7	Sudan	28	0	3	0	0	0	0	1			
8	Senegal	25	5	3	0	0	0	3	0	1		
9	Tanzania	23	3	0	0	5	1	0	0	0	1	
10	Congo	21	5	0	0	0	0	0	0	0	0	1

Table 4: Contributions of countries outside Sub-Saharan Africa to Sub-Saharan Africa's COVID-19 research

		Publication number	USA	UK	Canada	Australia	Italy	Germany	France	China	India	Belgium	No of countries collaborated with
1	South Africa	458	144	118	47	55	43	47	23	17	31	31	10
2	Nigeria	176	32	40	13	13	8	8	4	13	13	6	10
3	Kenya	74	28	28	11	11	4	7	4	3	0	5	9
4	Uganda	51	18	16	0	3	4	0	3	5	9	4	8
5	Zimbabwe	37	10	10	3	2	0	0	4	0	0	3	6
6	Cameroun	36	14	10	4	3	5	5	13	4	3	3	10
7	Sudan	28	0	7	3	0	6	4	3	5	3	0	7
8	Senegal	25	17	10	3	0	0	0	6	4	0	4	6
9	Tanzania	23	7	9	0	2	0	4	3	3	0	0	4
10	Congo	21	8	9	0	0	4	5	0	0	0	3	5

3.3 Funding ~~Organization~~ of Africa's COVID-19 Research Contribution

243 articles received financial support from a total of 159 different funding organizations across 38 countries. The funding organizations provided 349 funding supports, as some articles received multiple funding supports. Only (13/159) 8.18% of the funding organizations are within Africa and provided 40/349 funding supports or 11.46% of all the funding supports. Table SM2 in the supplementary document contains a list of 20 organizations that provided the highest number of COVID-19 research funding supports. The result also shows that the top five organizations that funded most COVID-19 research in Sub-Saharan Africa are in the USA, UK and EU. The National Institutes of Health, Bill and Melinda Gates Foundation, Wellcome Trust, and Horizon 2020 Framework Programme were the top five organizations that funded COVID-19 research in Africa. Further analysis of the national affiliations of funding agencies is presented in Table 5 below. This analysis shows that, within Sub-Saharan Africa, most of the organizations that funded COVID-19 research are within South Africa. Most of the funding agencies are USA, UK and French organizations. Table 5 also shows that only six Sub-Saharan African countries (South Africa, Kenya, Zambia, Mauritius, Nigeria, and Botswana) funded COVID-19 research. Similarly, 65.15% of all the funding originating in Sub-Saharan Africa came from South African organizations. This same skewed trend was observed in the amount of funding from countries outside Sub-Saharan African region. USA provided 35.07% of all the funding; twice more than the UK (17.51%) and three times more than EU (10.9%). These two top countries and the EU funded more than 60% of all COVID-19 research from Sub-Saharan Africa.

Table 5: Location of the top Funding agencies and Number of Funded articles per Country

Outside Sub-Saharan Africa				Sub-Saharan Africa			
	Country name	Number (% of total)			Country name	Number (% of total)	
		Agencies	Funded articles			Agencies	Funded articles
1	USA	54 (33.96)	122 (35.07)	1	South Africa	6 (3.77)	26 (7.45)
2	UK	22 (13.84)	61 (17.51)	2	Kenya	3 (1.89)	6 (1.72)
3	France	7 (4.40)	10 (2.88)	3	Zambia	1 (0.63)	3 (0.86)
4	China	6 (3.77)	10 (2.88)	4	Mauritius	1 (0.63)	3 (0.86)
5	Germany	6 (3.77)	7 (2.02)	5	Nigeria	1 (0.63)	1 (0.29)
6	EU[1]	5 (3.15)	38 (10.9)	6	Botswana	1 (0.63)	1 (0.29)
7	Canada	4 (2.51)	7 (2.02)		**Total**	**13(8.18)**	**40(11.46%)**
8	Brazil	4 (2.51)	4(1.16)				

3.4 Collaboration Pattern

The result of the collaboration analysis is visualized in Fig. SM2 in the supplementary file. The analysis of collaboration shows that single author (otherwise called "no collaboration") papers, constituted 14.46% of all the papers that were published. International collaboration, which was the most popular collaboration type, constituted 55.84% of all published papers (i.e., 55.84% of papers were collaborations between Sub-Saharan Africa and other regions). This implies that only

[1] A regional government

44.16% of all the co-authored articles were published without contribution from outside Sub-Saharan Africa. There is a need for rapid global collaboration to understand and create vaccines and therapeutic solutions for the COVID-19 disease. This analysis indicates that Africa participates in the global cooperation on COVID-19 research.

Only 4.11% of the published COVID-19 papers were written as a product of collaboration between Sub-Saharan African countries and without contributions from outside the region. This corroborates earlier studies which showed low scientific interaction between African countries (Asubiaro, 2019; Onyancha & Maluleka, 2011). While Sub-Saharan Africa's participation in global COVID-19 collaboration is a great development for research visibility and healthcare delivery in the region, there is also a need to expand pan-Africa collaboration that will focus on health research in which individuals of African descent will be properly represented. Past global collaborations have brought notable improvements to health care delivery in Africa. For instance, the United States was the major collaborator with Sub-Saharan African countries in combating the Ebola virus pandemic which ravaged West African countries in 2014 and 2015(Frieden & Damon, 2015). The United States funded and provided personnel for most of the research in vaccine development, disease detection, control, and prevention. Similarly, the World Health Organization (WHO) plays a vital role in the development of policies and action plans as well as in the provision of drugs and medical equipment for healthcare delivery in many African countries. For instance, the WHO implemented cost-effective interventions for the early detection and management of Non-Communicable Diseases (NCDs) through its WHO Package of Essential NCD interventions (WHO PEN). WHO PEN plays a significant role in health care delivery for diseases such as cardiovascular disease, cancer, and diabetes in African countries (Tesema et al., 2020).

However, studies have highlighted some of the biases against African countries in global health collaboration. For instance, studies have shown that there is a disproportionate underrepresentation of individuals of African descent in global clinical trials for drugs and vaccines (Hamel et al., 2016; McGarry & McColley, 2016), which has led to limited availability of appropriate treatments and has created gaps in clinical care management approaches, subsequently resulting in potential poor health outcomes. Because genetic variations exist in "disease biology, presentation, and response to treatments" (Bhatnagar et al., 2017) among individuals of different races, it is necessary that members of all demographics (gender, race/ethnicity, or age group etc) are adequately represented in clinical trials to enhance the generalizability and reliability of trial outcomes (Clark et al., 2019). The underrepresentation of individuals of African descent in the participation of global clinical trials has been offered as a possible explanation for the ineffectiveness of some drugs among people of African descent, such as albuterol for asthma (Mak et al., 2018; Weiler, 2018), as well as uncertainty about the potency of Multiple Myeloma drugs in individuals of African descent (Bhatnagar et al., 2017).

The same trend of underrepresentation of Africans in drugs and vaccines clinical trials of drugs is already playing out in the ongoing COVID-19 pandemic. Statistics from a concluded COVID-19 clinical trial reveals the underrepresentation of individuals of African descent in the clinical trial of remdesivir for COVID-19 care (Chastain et al., 2020). On that note, there are also calls from the medical community for the inclusion of more Africans in subsequent COVID-19 clinical trials

(Stephenson & Ojikutu, 2020). While this call is justifiable, this study suggests funding and formal development of robust intra-African collaboration as the panacea to the problem of "healthcare solutions from abroad" that do not capture the realities in Africa. If adequate funding is provided, through collaboration, researchers from the region can develop solutions that cater to the specific COVID-19 needs of the African population.

3.5 Funding and Collaboration Patterns

The distribution of funded articles by collaboration type is visualized in Fig. SM1 in the attached supplementary file. Most of the funding was allocated to articles from international collaborations (57.20%), while only 4.94% was allocated to Sub-Saharan African collaborations. To describe this information in another dimension, analysis of the proportion of collaboration types that were funded is presented on Table SM3 in the supplementary file, 32.43% of Sub-Saharan African collaborations were funded, followed by international collaborations (27.69%), institutional collaboration (24.56%), national collaboration (24.56%) and single authorship (23.08%) were funded. In other words, there were few Sub-Saharan African collaboration articles, but its funded proportion is slightly higher than other collaboration types. While high international collaboration between Sub-Saharan Africa and the rest of the world is a positive trend, there are indications from earlier studies that funding and the resultant high visibility are major drives for this type of scientific alliance (Asubiaro, 2019; Asubiaro, 2018; Owusu-Nimo & Boshoff, 2017). Low pan-African research collaboration could be explained by the dearth of research funding for pan-African research and collaboration both in general and on COVID-19 specifically. Pan African research collaborations are sacrosanct to Africa's desired development as imported solutions to Africa's challenges have not been optimal. Pan-African research collaboration on COVID-19, driven through adequate funding from national governments and regional organizations (like the African Unity (AU), Economic Community of West African States (ECOWAS), Southern African Development Community (SADC), East African Community (EAC), Economic Community of Central African States (ECCAS), and the Community of Sahel-Saharan States (CENSAD)), is a requisite for Africa to create medical solutions for both the ongoing pandemic and other diseases in Africa. While the South African government provided some funding, there was no indication that funding came from any of the regional organizations. It is evident from the earlier discussion that relying on medical research, including vaccine and drug development, from other parts of the world is not in the best interest of Africans and the panacea to this reliance may be strong pan-African research collaboration networks with adequate funding.

4 Conclusion and Recommendation

This study analyzed Sub-Saharan Africa's COVID-19 research output to understand the patterns of collaboration and funding. The result shows that Sub-Saharan Africa contributed about two percent of global research on COVID-19. South Africa contributed about 50% of all the COVID-19 publications from Sub-Saharan Africa while USA (28.48%) and the UK (24.47%), the top two external national contributors, collaborated with Sub-Saharan African countries three times more than any other country. Papers resulting from collaborations between Sub-Saharan African countries, without contributions from outside the region, were less than five percent of the total

output, whereas more than half of the papers were written in collaboration with researchers from outside the region.

Organizations from the USA, UK and EU funded more than 60% of all COVID-19 research from Sub-Saharan Africa. More than 60% of all funding from a Sub-Saharan African country came from South African organizations. This study provides evidence that pan-African COVID-19 research collaboration is low, perhaps due to poor funding and institutional support from Africa. Considering the harms caused by the long-term underrepresentation of individuals of African descent during the development of solutions to health problems, it is recommended that pan-African research collaboration networks be funded and supported by Africa's national and regional government organizations, with the specific objective of creating customized solutions for Sub-Saharan Africa.

As indicated in the results which show little interaction between Sub-Saharan African countries, it is recommended that health research stakeholders foster more intra-African collaborations through the provision of *ad-hoc* intra-African COVID-19 research funding and grants. It is also recommended that the result of this and similar studies should be used in advocacy for intra-African collaboration promotion and for the solicitation of funding from governmental and non-governmental funding agencies. As indicated by the fact that regional African governments' COVID-19 research funding has not resulted in published papers as of September 2020, there is a need for stakeholders to specifically advocate for COVID-19 research funding from these organizations. There is also a need for national and state governments to contribute to COVID-19 research.

Suggestions for future research include the analysis of internal and external collaboration research topics to understand the subjects that are covered in COVID-19 research at each level of collaboration. It is acknowledged that COVID-19 is an ongoing pandemic, and this study does not provide an analysis of the contribution of Africa to the overall body of research on COVID-19. Instead, this study provided a snapshot of Sub-Saharan Africa's contributions with the aim of contributing knowledge that can be used for improving COVID-19 research in the region.

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A.T.V. conceived the research idea, collected and analyzed data, and wrote the manuscript. S.H. took part in the data coding and manuscript writing.