

Sub-Saharan African Countries' COVID-19 Research: An analysis of the External and Internal Contributions, Collaboration Patterns and Funding Sources

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Abstract:

This study aims at providing some evidence-based insight into Sub-Saharan Africa's first eighteen months of COVID-19 research by evaluating its research contributions, patterns of collaboration, and funding sources. Eighteen months (2020 January 1-2021 June 30) COVID-19 publication data of 46 Sub-Saharan African countries was collected from Scopus for analysis. Country of affiliation of the authors and funding agencies data was analyzed to understand country contributions, collaboration pattern and funding sources. USA (23.08%) and the UK (19.63%), the top two external contributors, collaborated with Sub-Saharan African countries about 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 that are in USA and the UK funded 45% of all the COVID-19 research from Sub-Saharan Africa. 53.44% 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 lack of institutional support within Sub-Saharan Africa. This mirrors the collaborative features of science in Sub-Saharan Africa before the COVID-19 pandemic. The high volume of international collaboration during the pandemic is a good development. There is also a strong need to forge more robust pan-African research collaboration networks, through funding from Africa's national and regional government organizations, with the specific objective of meeting local COVID-19 and other healthcare needs.

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. (2021) 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. Another data-driven study also used bibliometric methods and focused on the productivity of the Sub-Saharan African countries, scope and topics of interest, and authorship position of African researchers (Guleid et al., 2021). While this study adopted the same research methodology as Guleid *et al.*, (2021), the focus is different as this study's focus is to find out the collaboration pattern, funding sources, and contributions from countries in and outside Sub-Saharan Africa's country. It is intended that the information provided in this study can help in decision making going forward, as the COVID-19 pandemic is an ongoing phenomenon. 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 the selected Sub-Saharan Africa COVID-19 research, and
3. investigate the sources of funding for COVID-19 research in Sub-Saharan Africa.

1.1 *Research Context and Motivation*

Features of research in Sub-Saharan Africa before the pandemic is well documented in the literature. For instance, collaboration pattern studies reveal Sub-Saharan Africa's researchers mostly collaborate with local peers in their countries or outside the continent of Africa, with low research synergy between Sub-Saharan African countries through collaboration (T. Asubiaro, 2019; Onyancha, 2020; Onyancha & Maluleka, 2011). While high inclination towards international collaboration is a great development because of visibility and opportunity to attract funding, the low pan-African research synergy is a great concern. International collaboration in itself is a measure of development, however, some feelers are of the opinion that international collaboration in Sub-Saharan Africa has led to "research neocolonialism" because of inequality in authorship when researchers in Africa participate in international collaboration and the undue influence of the colonial power on the research activities in the Sub-Saharan African countries

they once colonized (Boshoff, 2009; Hedt-Gauthier *et al.*, 2019; Owusu-Nimo and Boshoff, 2017). For instance, studies have revealed that researchers in Africa mostly participate in international collaboration as fringe participants, not as the first authors or principal investigators (Hedt-Gauthier *et al.*, 2019; Owusu-Nimo & Boshoff, 2017). Another study revealed that Sub-Saharan African countries collaborated more with the countries that colonized them (T. V. Asubiaro & Badmus, 2020; Boshoff, 2009). Countries that were colonized by England were more likely to collaborate with England and English-speaking countries and same for countries that were colonized by Portugal and France. Studies have recommended an increase in synergy between African countries to balance the skewness against pan-African collaboration. Onyancha, (2020) recommended a three-throng collaboration model that with balanced representation of national, regional and international collaboration types.

Similarly, research has also shown the research in Sub-Saharan Africa is underfunded. At the heart of the underfunding problem is the passive attitude of governments in Sub-Saharan African countries, as most of these countries do not prioritize research like their counterparts in the west. While significant proportion of research funding in Sub-Saharan Africa comes from foreign countries, yet many research projects that are sponsored by foreign countries fail because Sub-Saharan African countries cannot provide counterpart funding, which are usually a fraction of the amount provided by foreign donors (Bendana, 2019). It could be argued that most of the countries in Sub-Saharan African region are poor, the proportion of their budgets they allocate to research compared to mundane items suggest their attitude has exacerbate the situation. Sub-Saharan Africa invested an average of 0.4% of its GDP on research in 2017, lower than the global average of 1.7% (The UNESCO Institute for Statistics, 2020). With population growth that is above global average, spending on research has not grown at the same pace. While Sub-Saharan Africa gained an 12.5% additional percentage point of world population between 2007 and 2013, gross domestic expenditure on research grew by just 0.1% (UNESCO, 2015).

The COVID-19 pandemic has brought unprecedented changes to research in the world in many ways. Research funding on COVID-19 by 11th of March, 2020 (exactly a year after COVID-19 was declared a pandemic by the World Health Organization) by United States' National

Institutes of Health (NIH) had surpassed \$3.6 billion¹, more than the global funding on neglected diseases such as HIV/AIDS, malaria, tuberculosis, cholera, diarrhoeal, Hepatitis B and C, pneumonia, meningitis and dengue which stood at \$2.58 billion (Chapman et al., 2020). Globally, it was estimated that about \$9.2 billion was committed to COVID-19 research between January and September 2020, apart from additional \$25 billion that was pledged to support the manufacture and distribution of vaccines and treatments. In comparison, a total of \$11.6 billion was invested in the research of neglected diseases in three years-2017 to 2019 (Chapman et al., 2020).

COVID-19 changed the research landscapes as we know it, as it became the focus in the research community. Huge resources were diverted, while many researchers were re-deployed to COVID-19 research. For instance in the UK, clinical academics were drafted to projects involving therapeutic trials for COVID-19 (Alam et al., 2021). The changes in the research landscape was reflected in many bibliometric studies of the COVID-19 literature. The volume of literature is unprecedented because of the urgency in attention to the COVID-19 pandemic (Belli et al., 2020) at 100 publications and 1600% growth rate (Pal, 2021). With “COVID” surpassing the likes of other acronyms such as “AIDS”, “PCR” and “MRI”, that have been in existence for more than thirty years, in just one year (Barnett & Doubleday, 2021), studies have declared COVID-19 as the most disruptive “phenomenon for research” because of the explosion of research activities as reflected in citation and (Fassin, 2021), speed of publication which has led to an increase in retractions (Moradi & Abdi, 2021; Soltani & Patini, 2020).

Understanding if and how the changes in the global research system due to COVID-19 reverberates in Sub-Saharan Africa is the motivation for this study. One of the questions this research aims to answer is: how has Sub-Saharan African countries synergized to combat this disease through collaborative research? While governments in other parts of the world increased funding for research by making provision for COVID-19 research funding, it behoves the scientific stakeholders in Sub-Saharan Africa to understand how governments in Sub-Saharan African countries responded as well. While

2. Methodology

¹ <https://web.archive.org/web/20210311020119/https://covid19.nih.gov/funding>

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 5th of July 2021 to capture publications from the eighteen months (January 2020-June 30 2021). 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 all the names of the 46 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" OR "Ghana" OR "Ethiopia" OR "Botswana" OR "Gabon" OR "Eritrea" OR "Guinea-Bissau" OR "Equatorial Guinea") 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 "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 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 178,780 scientific publications records with 5312 (2.97%) 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. However, with a contribution of about 3% from Sub-Saharan Africa alone, this is an improvement in the contribution of the region to global scientific output. 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 about than 60% of all document types. Letters, reviews, notes, and editorial materials are the other notable document types.

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

	Global contribution		Sub-Saharan African contribution	
1	Article	59.27%	Article	65.06%
2	Letter	12.27%	Review	13.60%
3	Review	10.76%	Note	7.92%
4	Note	6.41%	Letter	7.37%
5	Editorial	5.55%	Editorial	3.76%
6	Conference Paper	3.40%	Conference Paper	2.03%
7	Short Survey	0.89%	Short Survey	0.81%
8	Erratum	0.72%	Book Chapter	0.69%
9	Book Chapter	0.42%	Data Paper	0.38%
10	Conference Review	0.19%	Erratum	0.29%
11	Data Paper	0.08%		
12	Book	0.03%		
13	Retracted	0.01%		
14	Preprint	0.001%		

The second comparison was contributions by discipline, which also reveal some similarities between the global and Sub-Saharan African responses: Medicine constituted about 60% 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 2. Secondly, global and Sub-Saharan Africa's COVID-19 research focused on four major disciplines- that constituted at least 5% of the total number of COVID-19 publications. Few differences in the disciplinary contributions include Social Sciences, and Agricultural and Biological Sciences disciplines that received more attention in Sub-Saharan African than at the global stage.

Table 2: Comparison between Global and SSA' contribution by Discipline

	Global Contribution		Sub-Saharan Africa	
1	Medicine	65.01	Medicine	60.41
2	Social Sciences	12.06	Social Sciences	17.07
3	Biochemistry, Genetics and Molecular Biology	10.08	Biochemistry, Genetics and Molecular Biology	9.70
4	Immunology and Microbiology	6.57	Immunology and Microbiology	7.51
5	Computer Science	5.41	Environmental Science	5.44
6	Environmental Science	4.82	Agricultural and Biological Sciences	4.48

7	Nursing	4.51	Multidisciplinary	4.37
8	Engineering	4.37	Pharmacology, Toxicology and Pharmaceutics	3.78
9	Pharmacology, Toxicology and Pharmaceutics	4.24	Psychology	3.75
10	Psychology	3.60	Business, Management and Accounting	3.73
11	Business, Management and Accounting	2.86	Computer Science	3.61
12	Multidisciplinary	2.76	Engineering	3.31
13	Neuroscience	2.73	Nursing	3.14
14	Economics, Econometrics and Finance	2.33	Economics, Econometrics and Finance	3.11
15	Health Professions	2.29	Arts and Humanities	3.09
16	Agricultural and Biological Sciences	2.24	Mathematics	2.79
17	Arts and Humanities	2.22	Health Professions	2.41
18	Mathematics	2.20	Neuroscience	2.01
19	Physics and Astronomy	1.80	Physics and Astronomy	1.39
20	Chemistry	1.70	Chemistry	1.37
21	Energy	1.36	Decision Sciences	1.17
22	Decision Sciences	1.25	Earth and Planetary Sciences	1.13
23	Chemical Engineering	1.12	Energy	1.11
24	Materials Science	1.10	Chemical Engineering	0.60
25	Earth and Planetary Sciences	0.95	Materials Science	0.60

3.1 Productivity of Countries in and outside Sub-Saharan Africa

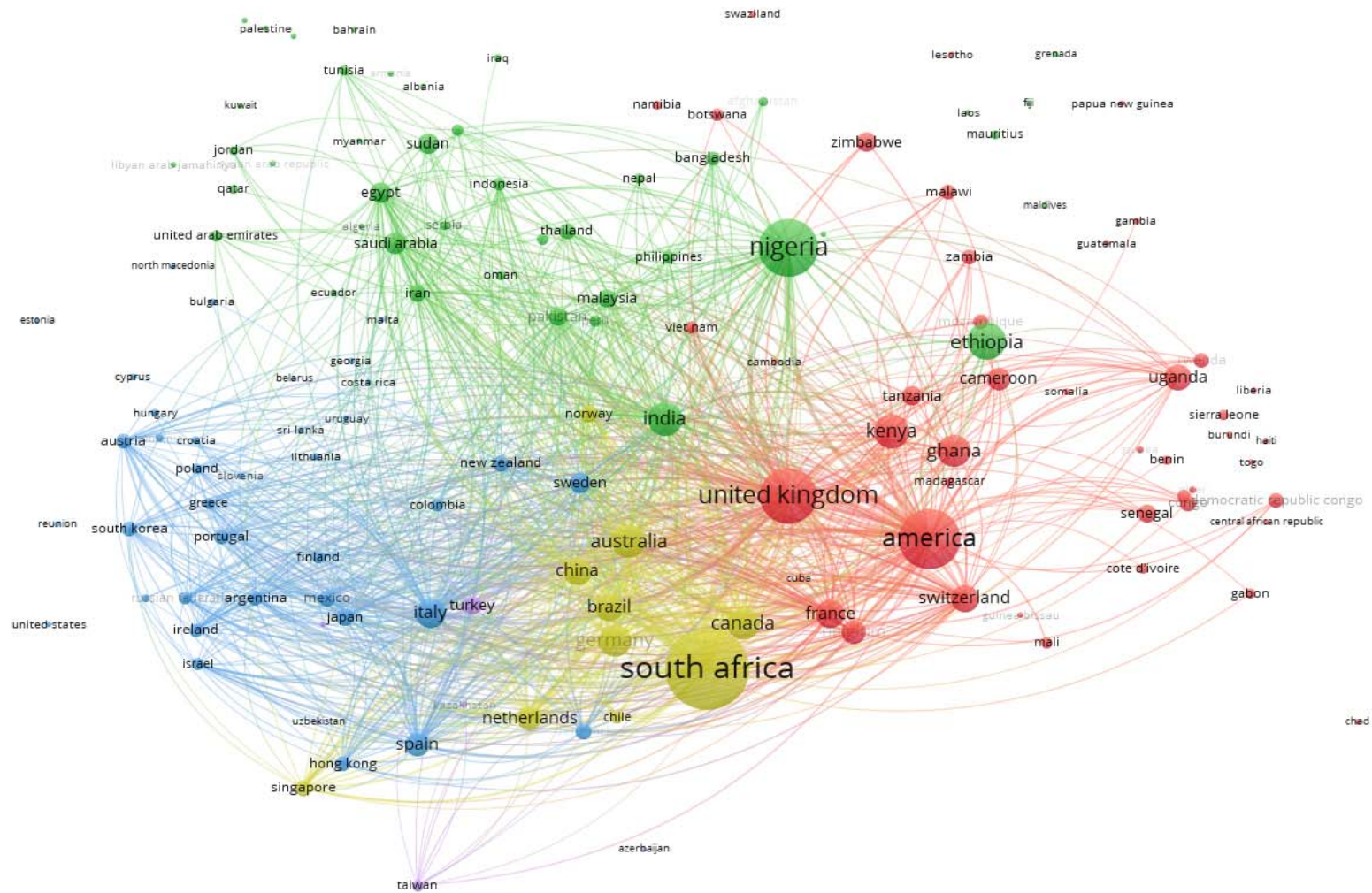
The number of publications from the top twenty most productive Sub-Saharan countries and the number of publications in which countries from outside Sub-Saharan Africa contributed is presented on Table 3 and visualized in a network map in Figure 1. The result shows that South Africa contributed to 41.85% of all the publications from the 46 Sub-Saharan African countries. Other substantial contributions are from Nigeria (21.03%), Ethiopia (8.94%), Kenya (7.30%), and Ghana (6.89%). Together, contributions from South Africa and Nigeria constitute about 63% of all the publications from Sub-Saharan Africa. The results also show that the United States of America (USA) (23.08%) and the United Kingdom (UK) (19.63%) each collaborated with Sub-Saharan African countries on COVID-19 research on about 20% of all publications; each of these two countries collaborated with sub-Saharan Africa almost three times more than other countries. Other countries such as India (7.27%), Australia (6.91%), Canada (6.63%), Germany

(6.36%) and Italy (5.74%) also each collaborated on greater than 6% of the publications from Sub-Saharan Africa on COVID-19.

Table 3: 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	41.85	1	United States	23.08
2	Nigeria	21.03	2	United Kingdom	19.63
3	Ethiopia	8.94	3	India	7.27
4	Kenya	7.30	4	Australia	6.91
5	Ghana	6.89	5	Canada	6.63
6	Uganda	4.25	6	Germany	6.36
7	Cameroun	3.28	7	Italy	5.74
8	Sudan	2.71	8	France	5.23
9	Zimbabwe	2.60	9	China	4.86
10	Tanzania	2.39	10	Brazil	4.82
11	Senegal	2.16	11	Switzerland	4.74
12	Congo	1.71	12	Spain	3.84
13	Malawi	1.54	13	Belgium	3.77
14	Zambia	1.51	14	Netherlands	3.73
15	Mali	1.67	15	Saudi Arabia	3.24
16	Mozambique	1.45	16	Sweden	2.88
17	Rwanda	1.43	17	Egypt	2.80
18	Democratic Republic of Congo	1.39	18	Malaysia	2.26
19	Burkina Faso	1.02	19	Pakistan	2.24
20	Botswana	1.00	20	Turkey	2.09
	Benin	0.78			

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 further shows the contributions of Sub-Saharan African countries to each others' research through collaboration. The results show that only South Africa made contributions to research in every other SSA countries in the top ten most productive category. Contributions from South Africa seem widespread, and do not appear to be dependent on proximity and language. For instance, while Zimbabwe, and Kenya 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 Sudan are not. Uganda's contribution to Tanzania's COVID-19 research is also significant. Considering Kenya's contribution 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 4 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 the top ten most productive category. In addition, some countries are scientifically isolated among Sub-Saharan African countries. For instance, Zimbabwe and Sudan collaborated with just one and two other Sub-Saharan African countries, respectively. Table 3 also shows a trend: Sub-Saharan countries that produced fewer COVID-19 studies also collaborated with fewer countries in the region. This result concerning the contribution of the Sub-Saharan African countries to each others research 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 5 was created. Table 5 shows the contributions of countries from other world regions to Sub-Saharan African countries' COVID-19 research. Comparison between results on Tables 4 and 5 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, South Africa is the only country that contributed to every other Sub-Saharan African countries in the top ten most productive category, on the other hand, four countries from the region (South Africa, Nigeria, Kenya, and Ghana) collaborated with all the top contributing countries from outside the region. Furthermore, On the average, all the 10 most productive Sub-Saharan African countries collaborated with seven of the top ten collaborating countries from outside the region. 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 4: Contribution of SSA countries to each other's COVID-19 Scientific Contribution

		Publication number	South Africa	Nigeria	Ethiopia	Kenya	Ghana	Uganda	Cameroun	Sudan	Zimbabwe	No of connections
1	South Africa	2221										9
2	Nigeria	1115	147									8
3	Ethiopia	473	20	31								4
4	Kenya	386	73	61	23							7
5	Ghana	365	61	50	0	31						6
6	Uganda	226	41	31	14	33	19					7
7	Cameroun	173	27	22	0	20	18	16				5
8	Sudan	144	14	21	0	0	0	0	0			2
9	Zimbabwe	138	51	0	0	0	0	0	0	0		1
10	Tanzania	126	19	19	0	20	14	18	0	0	0	5

Table 5: Contributions of countries outside Sub-Saharan Africa to Sub-Saharan Africa's COVID-19 research

		Publication number	USA	UK	India	Australia	Canada	Germany	Italy	France	China	Brazil	No of countries connected with
1	South Africa	2221	561	478	165	215	172	165	166	105	95	153	10
2	Nigeria	1115	221	237	114	62	79	56	54	32	70	52	10
3	Ethiopia	473	72	51	40	13	23	13	0	0	12	0	7
4	Kenya	386	164	135	45	41	45	34	31	27	18	31	10
5	Ghana	365	100	102	32	36	35	41	17	15	29	24	10
6	Uganda	226	88	68	28	22	25	0	18	0	13	17	8
7	Cameroun	173	60	39	18	18	17	14	13	32	0	15	9
8	Sudan	144	26	40	19	0	0	0	19	0	15	0	6
9	Zimbabwe	138	33	38	0	0	0	0	0	0	0	0	3
10	Tanzania	126	41		15	16	0	15	0	0	0	0	5

3.3 *Africa's COVID-19 Research Funding*

A total of 1085 articles received financial support from a total of 1204 different funding organizations across 78 countries. The funding organizations provided 3496 funding supports, as some articles received multiple funding supports; there were only 3215 funding supports from 962 identifiable funding organizations were analyzed. Only (13/159) 8.18% of the funding organizations are within Africa and provided (40/349) 11.46% of all the funding supports. Table 7 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 Canada. The National Institutes of Health, Wellcome, Bill and Melinda Gates Foundation, South African Medical Research Council, SAMRC, and Medical Research Council, MRC 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 6 below. Sub-Saharan African countries and regional organizations provided 10.61% of all the grants and housed 6.76% of the funding agencies. This analysis shows that, of the funding organizations in Sub-Saharan Africa, most are located in South Africa (53.44%), and they provided 77.34% of all the grants from the region. Most of the funding agencies are USA, UK and French organizations. Table 6 also shows that funding organization in eleven Sub-Saharan African countries (South Africa, Ethiopia, Nigeria, Uganda, Ghana, Côte d'Ivoire, Tanzania, Botswana, Mauritius, Kenya, and Mozambique) funded COVID-19 research.

Global organizations like the World Bank, World Health Organization etc provided 106 grants from 31 funding agencies. Regional governments- European Union provided 215 grants from 26 funding agencies. Regional organizations from Sub-Saharan Africa provided 32 grants from five funding agencies. Other regional governments from Austrasia and Asia both provided 4 grants each from one funding agency. This same skewed trend was observed in the amount of funding from countries outside Sub-Saharan African region. USA provided 29.14% of all the funding; almost twice more than the UK (16.77%) and eight times more than Canada (3.83%). The two top countries (USA and the UK) provided about 45% of all COVID-19 research fundings for Sub-Saharan Africa.

Table 6: 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	No of grants			Agencies	No of grants
1	USA	260 (27.03)	962 (29.14)	1	South Africa	31 (3.77)	239 (7.43)
2	UK	101 (10.50)	539 (16.77)	2	Ethiopia	8 (0.83)	28 (0.87)
3	Canada	51 (5.30)	123 (3.83)	3	Nigeria	6 (0.62)	17 (0.53)
4	Germany	31 (3.42)	110 (3.42)	4	Uganda	3 (0.31)	7 (0.22)
5	China	41 (4.26)	99 (3.08)	5	Ghana	3 (0.31)	6 (0.19)
6	Spain	22 (2.29)	69 (2.15)	6	Tanzania	2 (0.21)	3 (0.09)
7	France	21 (2.18)	63 (1.96)	7	Côte d'Ivoire	1 (0.10)	3 (0.09)
8	Switzerland	23 (2.39)	62 (1.93)	8	Botswana	1 (0.10)	2 (0.06)
9	Australia	27 (2.81)	50 (1.56)	9	Mauritius	1 (0.10)	1 (0.03)
10	Brazil	11 (1.14)	43 (1.34)	10	Kenya	1 (0.10)	1 (0.03)

Result of the top 20 funding agencies that sponsored COVID-19 research from Africa is presented in Table 7. The result shows a good spread of funding agencies, this is a positive trend. The top five agencies funded 15.9% of all the publications. Organizations from only one Sub-Saharan African country-South Africa- was represented in the top twenty countries in which funding agencies are located. Organization from USA, followed the UK, Canada, Germany and China were represented in the top twenty funding agencies for COVID-19 research from Sub-Saharan Africa.

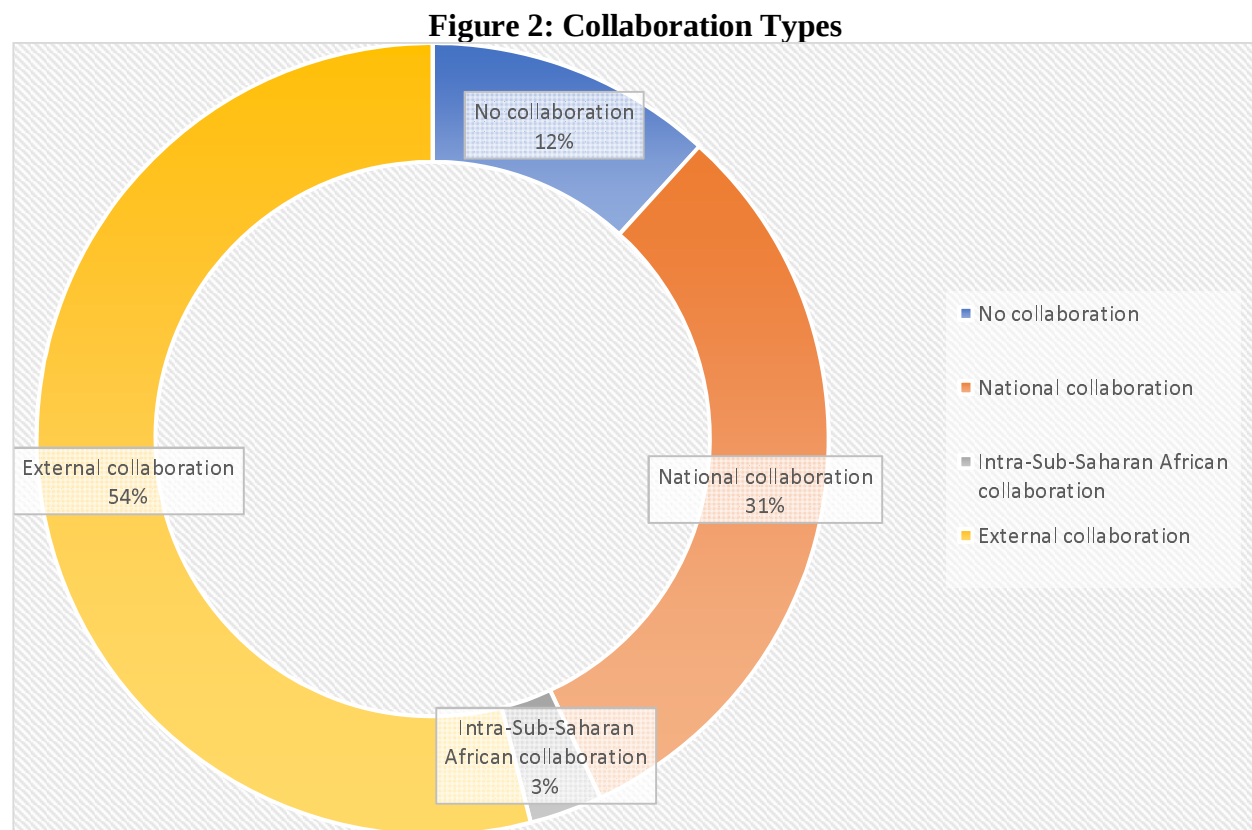
Table 7: Top 20 Funding Organizations for COVID-19 research contributed to by researchers that are affiliated with Institutions from Africa

Rank	Funding organization	Location	% of articles funded
1	National Institutes of Health, NIH	USA	155 (4.82)
2	Wellcome	United Kingdom	118 (3.67)
3	Bill and Melinda Gates Foundation, BMGF	USA	107 (3.33)
4	South African Medical Research Council, SAMRC	South Africa	72 (2.24)
5	Medical Research Council, MRC	United Kingdom	59 (1.84)
6	National Research Foundation, NRF	South Africa	58 (1.80)
7	National Institute for Health Research, NIHR	United Kingdom	58 (1.80)
8	Horizon 2020	European Commission	56 (1.74)
9	World Health Organization, WHO	Global Organization	48 (1.49)
10	European Commission, EC	European Union	48 (1.49)
11	Department for International Development, UK Government, DFID	United Kingdom	43 (1.06)
12	European and Developing Countries Clinical Trials	European Union	41 (1.28)

	Partnership, EDCTP		
13	Fogarty International Center, FIC	USA	38 (1.18)
14	National Institute of Allergy and Infectious Diseases, NIAID	USA	34 (1.06)
15	National Natural Science Foundation of China, NSFC	China	30 (0.93)
16	National Science Foundation, NSF	USA	30 (0.93)
17	UK Research and Innovation, UKRI	United Kingdom	26 (0.81)
18	Centers for Disease Control and Prevention, CDC	USA	26 (0.81)
19	National Institute of Mental Health, NIMH	USA	21 (0.65)
20	United States Agency for International Development, USAID	USA	20 (0.62)

3.4 Collaboration Types

The result of the collaboration analysis is visualized in Figure 2. 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 products of collaborations between Sub-Saharan Africa and other regions). This implies that only 44.16% of all the 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

An analysis of the proportion of collaboration types that were funded is presented on Table 8. Most of the funding was allocated to articles from international collaborations (57.20%), while only 4.94% was allocated to Sub-Saharan African collaborations.

Table 8: Percentage of collaboration type that received funding

		Funding Status		Total
		Not funded	Funded	
Collaboration Type	No collaboration	594 (95%)	31 (5%)	625
	National collaboration	1465 (88.2%)	196 (11.8%)	1661
	Intra-Sub-Saharan African collaboration	141 (89.2%)	17 (10.8%)	158
	External collaboration	2027 (70.7%)	841 (29.3%)	2868
Total		4227 (79.6%)	1085 (20.4%)	5312

International collaboration (29.3%) received the highest percentage of funding, followed by national (11.8%) and intra-Sub-Sub-Saharan African collaborations (10.8%). In other words, international collaborations were three times more likely to be funded articles than national and intra-Sub-Saharan African collaboration and six times more likely to be funded than single author papers. 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 and 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 Union, Economic Community of West African States, Southern African Development Community, *East African Community*, Economic Community of Central African States, and the Community of Sahel-Saharan States), 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 to about 40% of all the COVID-19 publications from Sub-Saharan Africa while USA and the UK, the top two external national contributors, collaborated with Sub-Saharan African countries about 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 and UK funded more than 45% of all COVID-19 research from Sub-Saharan Africa. More than 50% 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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