Ten years of biomedical research in West Africa (2005–14): A study of the ten most productive countries

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ABSTRACT

The objective of this research is to determine (i) the quantity and quality of publications in biomedical research in top-producing countries in West Africa during 2005–2014, as well as (ii) the characteristics of the journals used by the researchers and collaborative evidence in the area. Data was drawn from MEDLINE/PubMed and Google Scholar, while the impact factors of the journals were retrieved from the SCImago Journal and Country Rank portal. Quantity of publications was measured by counting the number of publications attributable to a country while h-index was extracted to measure quality. Productivity was analysed by sorting the data according to their first named authors, journals and publication dates, and analysed using MS Excel and LOTKA®. Nigeria, Ghana, Senegal, Burkina Faso and Mali had the highest number of publications. In respect to productivity, apart from Côte d'Ivoire that had an α value of less than 2, indicating a higher level of productivity, all other countries had an α value greater than 2. West African Journal of Medicine is the only journal of West African origin in the list of top ten journals where the authors from the sub-region published their papers, and it ranked tenth in the top twenty journals used. Nigeria and Ghana published more research in local journals in comparison with other countries, but these journals have very low mean impact factors. This study reinforces the need for improved research production and collaboration between the big and small countries.

Key words: Biomedical; West Africa; impact factor; productivity

INTRODUCTION

Biomedicine is the branch of medicine that is concerned with the application of the principles of the natural sciences and especially biology and biochemistry in clinical medicine (Porter 2004; Quirke and Gaudillière 2008; Lupton 2012). The ultimate aim of biomedical research is to answer questions leading to the discovery of treatment, prevention and diagnosis of diseases that cause illnesses and death. It also includes broad investigation of the underlying processes in living organisms; and determination of the effectiveness and safety of drugs, methods and devices used to diagnose, support and maintain individuals during and after treatment of diseases (European Medical Research Councils 2011). Similar to other fields, publications in biomedicine are the results of research of individual scientists or 'webs' of collaborators, both foreign and local, who share their scientific findings with the scientific community; and these publications could be used to measure progress in science (Hart 2000). These publications are definitive evidence of scientific activity.

According to UNDESA (2011), South Africa, Egypt and Nigeria which are among the top ten most populous countries in Africa, are also the top producers of scientific publications in the region. Many reports show that South Africa has consistently produced more biomedical and other research output than all other African countries (Uthman and Uthman 2007; Tijssen 2007 Hofman et al. 2009).

A number of bibliometric studies have examined scientific publications in sub-Saharan Africa (Uthman et al. 2007; Tijssen 2007; Hofman et al 2009), and in some specific African countries including Nigeria (Nwagwu 2005; 2006; 2007; 2010), Malawi (Gondwe and Kavinya 2008), Libya (Bakoush et al. 2007) and Egypt (Afifi 2007). While these studies show progress in biomedical research in Africa, performance status is not yet established when disaggregated by sub-regions (Uthman and Uthman 2009). The challenges include poor infrastructure, poverty and political instability (Ondari-Okemwa 2007). According to Grant, Shelby and Kenneth *(*2010), only a few countries in West Africa had the capacity for carrying out advanced training in nutrition and public health. Research exists that was carried out to analyse biomedical literature in some individual countries in West Africa (Nwagwu 2006; 2007), but there is not yet a study focusing on the quality, quantity and productivity of biomedical literature in West Africa as a sub-region.

The main objective of this study is to determine the quantity, impact, publication channels and collaborative evidence in biomedical literature in top-producing countries in West Africa during 2005 to 2014. Specifically, the study is designed to:

a) examine the quantity and distribution of biomedical publications by countries in West Africa during 2005 to 2014;
b) determine the quality/impact of the publications;
c) analyse the productivity patterns of the research in the top ten paper-producing countries; and
d) determine the characteristics of the most popular journals and authors.

Understanding the production and productivity patterns of the journals and authors as well as the most popular journals is a very important step for making informed policies that relate to research dissemination practices, sources and choices of journal in which to publish, and for the strengthening of research production and performance in West African countries. For journals, a recognized and important characteristic presently relates to whether they are available on an open access basis or not. An open access strategy of research dissemination has become the mantra of modern science, with the potentials of boosting wider spread and use of the outcomes of researchers' endeavours among larger audiences, as well as of interesting the public more than could be achieved by the traditional print model. Open access uptake globally has really gained ground during the period under study, but it has generally been slower in the Africa region in comparison with other regions (Nwagwu 2013). The access status of the journals – closed or open – gives an indication of the state of take-up of the publishing model by biomedical researchers in the sub-region. It also shows evidence of the commitment of researchers and their institutions to facilitating wider spread of their publications.

LITERATURE REVIEW

Scholarly publications

Scientific publications represent definitive evidence of the output of science, and bibliometrics provides the tools for understanding the characteristics of disciplines,

researchers and their communities through their publications. In this regard, publications can be collected, organized, and analysed to determine the size, quality and nature of research carried out in order to measure global, local, regional and national, and, individual, group and institutional practices and trends (King 1987; Nederhof and Zwaan 1991). Bibliometricians are also concerned with the productivity of scientists, measured primarily by the number of publications authored by scholars (Moed, De Bruin and van Leeuwen 1995). Beyond counting articles, several indices, such as those of Lotka's (1926) law have been used to establish and monitor the pattern of productivity of different categories of scientists. Studies based on these metrics, both empirical and conceptual, are now relatively ubiquitous in the literature (Nwagwu 2005).

Another important issue about publications relates to whether articles are used by other researchers, or how the papers influence other researchers. To this extent, researchers always talk about citation of research papers. Metrics of citation have been used to measure research quality and impact as well as in the mapping of science; for example, impact factor and the h-index are results of quantitative manipulations of citation data. The mapping of science based on publication statistics yields very crucial information in respect to sources of influence, and relationships among disciplines. Although citations and their metrics are very useful, their validity and reliability as measures for impact assessment have also been contentious issues. A major concern has come from the inherent limitations of citation databases – they are usually inadequate or biased in their coverage of countries, disciplines and languages of researchers (Bordons, Fernandez and Gomez 2002; van Leeuwen et al. 2001; Bollen et al. 2009). There also exist ambiguities and confusions caused by abbreviations and ordering of names of authors which make it difficult to attribute an article to one or more authors (Weingart 2005). These questions notwithstanding the issue of what the impacts of scholarly research means exactly and how citation data measure impact, are still used to understand quality of research. These challenges notwithstanding, many efforts aimed at studying the quality of research, have for a long time focused on data gathered at group levels such as institutions, disciplines, countries, and so the Thomson Reuter's Impact Factor comes in handy. But Hirsch (2005) devised a means of measuring the quality of scientific publications that is usable at group and individual levels known as the h-Index. Several studies have been carried out either using the Hirsch-index to evaluate research or to validate the approach (Hirsch 2005; 2007; Meho 2007; Bartneck and Kokkelmans 2011; Ferrara and Romero 2013).

Scientific collaboration

Collaboration, often measured by co-authorship or the number of authors that write a single paper is also a very important index in understanding the characteristics of publications. Who an author collaborates with, his or her status in the collaboration in terms of roles played, may manifest itself in the position of the author on the paper and the country of origin are important indices in studying the complexity of subjects, social interaction among scholars, sources of influence and so forth. Several studies have shown the significance of co-authorship in science, particularly in biomedicine where the practice is very heavy (King 2009). Many explanations have been proffered for this observation, which border mainly on the complexity of the structure and ethnography of the field of biomedicine. Some of the explanations are structural. For instance, Cronin (2001) has observed that biomedical practice requires intense socialization and oral communication, and so do all aspects of its organizational structure and value system. King also added that biomedical research often involves multi-level processes of decision-making and cross-

examination of the decisions; the discipline has a very strong apprenticeship system and thrives with practitioners working in groups. Also, in biomedical research, reliance on expert advice and control is usually strictly adhered to. As a result, the field is mentor-driven because it often involves extensive supervision from superior experts and team participation is required among peers.

Very crucially and related to the above, biomedical research focuses on human lives directly or indirectly, and this reinforces the extensive supervision requirement of the field (King 2000). In most instances, biomedical scientists work in closed groups with a single supervisor monitoring relatively large number of apprentices in different groups. Even long after training, medical practice is usually carried out in teams, whose composition often reflects both different levels of expertise and apprenticeship, and this promotes collaboration. Related to the above, King (2000) had observed that biomedicine is also becoming increasingly multidisciplinary, often requiring multi-expert inputs and interaction.

Biomedical literature in Africa

In Africa, there exist bibliometric studies in some countries in the region. For instance, Nwagwu (2006) carried out a bibliometric study of the quantity and quality of Nigeria's biomedical literature during the period 1962–2002, using data from PubMed. He found that about 52 per cent of all the journals that published papers on Nigeria did so only once each, whereas 48 per cent appeared more than once in the bibliography. Nwagwu established non-discrimination in biomedical researchers' use of channels, and suggested that this could be a result of a scramble to publish in any source that is willing to accept their papers, as well as an indication of the difficulty with which biomedical papers on Nigeria find their ways into international mainstream sources. Nwagwu's observed that the trend signifies that biomedical research in Nigeria was growing in multi-disciplinarity, requiring more and more multi-expert input and interactions.

Shortly after Nwagwu's study, Uthman and Uthman (2007) examined publication trends on HIV/AIDS in Africa by first authors between 1996 and 2005 and found that South Africa, Egypt and Nigeria were the most productive countries in terms of absolute number of publications indexed by PubMed. Owolabi, Bower and Ogunniyi (2007) and Hofman et al. (2009) had similar observations when they showed that South African and Nigerian researchers had higher output in biomedical literature compared to researchers from other sub-Saharan Africa countries. Uthman and Uthman (2007) also showed that South Africa and Gambia had the best performance based on number of research articles relative to Gross Domestic Product (GDP). They also observed that there was a continuous increase, and reassuring trends, in the production of research articles from all Africa's sub-regions even though the gross contributions of the region to global research production was rather limited. They concluded that for African countries to achieve prolonged significant growth in biomedical research requires embarking on economic catch-up trajectories, sustained capacity building, investments and upgrading of their science bases. Following Uthman and Uthman (2007), Ramos et al. (2008) studied tuberculosis literature in the region and showed that Gambia, Malawi and Guinea Bissau were the most productive countries when the data was normalized by GDP. In another study Uthman (2008) found that Nigeria has achieved a significant increase in the number of SCI publications and collaborations in HIV literature. Over 85 per cent of the articles were published in collaboration among two or more authors.

Boshoff (2009) introduced a new dimension in the effort to understand the structure of biomedical research in Africa region by investigating how neocolonialism manifests in research activities using structure of co-authorship of research papers in Central Africa, and focusing on participation of authors from the North. He found that in 80 per cent of times, papers of Central African origin were co-authored with authors from outside the region, and that 46 per cent of the papers have co-authors from Europe while 35 per cent were co-authored with authors from the former colonial power, France. In a similar study, Boshoff (2010) investigated how researchers in the fifteen countries in the Southern African Development Community (SADC) and other parts of Africa collaborated to conduct research during 2005–08. He found that when researchers in SADC collaborated, only 3 per cent of such research was jointly-authored by researchers from SADC countries and 5 per cent of those papers were jointly authored with researchers from other African countries outside SADC. On the other hand, 47 per cent of research from SADC was as a result of collaboration with scholars from high income countries, who also constituted the co-authors in most intra-regional and continental papers authored by SADC researchers. According to Boshoff, South African researchers dominated in co-authoring papers both in the continent and in the region. It should however be remarked that Boshoff's research focused on scientific research generally, and not on biomedical research.

The study of Grant, Shelby and Kenneth (2010) focused on West Africa, and analysed peer-reviewed articles on key public health nutrition topics, namely infant and young child feeding practices, selected micro-nutrient deficiencies, and the emerging problem of overweight and obesity. The data was collected from MEDLINE/PubMed and covered the period 1998 to 2008. Their result showed that the sub-region produced an average of 3,796 articles per year during the period. They showed that institutions located outside Africa provided primary authors for 46 per cent of the publications. They showed further that articles in English dominated other languages as they accounted for 90 per cent of the total number of articles, and that most of the studies were cross-sectional in nature. They concluded that despite the huge burden of nutritional challenges in the sub-region, evidence from peer reviewed literature suggests an insufficient attention to research in the area.

Chuang et al.'s (2011) study took a different perspective by assessing the bibliometric characteristics of public health-related research articles published by researchers in African institutions by checking for significant variation across regions in Africa. He discovered that the growth in the number of public health-related articles by researchers in African institutions had been promising; and the pattern of growth is expected to continue. He stated that several factors, like the global responses to AIDS launched by WHO in 1987, funding supports by donor agencies such as the IMF, World Bank and NGOs (local and international) greatly influenced how public health researchers' conducted their studies. Also, they found that the increase in international collaboration played a major role in the upward trend of the number of articles being published in public health, an observation he attributed to the dominance of French and English languages in the region.

Jonathan Christopher and Daniel (2010) showed that Nigeria plays an important connecting role in the collaborative network between Anglophone speaking countries and other African countries, although the connections were weak between neighbouring West African countries and strong with South Africa. They reported that Malawi, which has one-tenth of the annual research output of Nigeria, produced research of high quality that exceeded the world average benchmark while Nigeria hovered around half that impact

level. Furthermore, they found that there was a pair of axes running between Nigeria and Kenya which engaged a high proportion of Africa's research and linked the rest of the continent in collaborative networks. A study on a different subject matter altogether that examined the geography of Africa's cyberspace also linked Nigeria and Kenya in a network of web links (Nwagwu and Ibitola 2010). Jonathan Christopher and Daniel (2010) recognized that despite Nigeria's relative advantage in terms of GDP, Nigeria was not producing as much research as would be expected given the size of its economy, and that the value of its resources was not yet being felt in its knowledge base (Uthman 2009).

Linking the current ranking of scholarship with scientific productivity, Uthman (2010) found that the better the economic ranking of a country, the higher the quantity of its research productivity. He observed however that even though Nigeria was ranked fifth in Africa in terms of the relative contribution to the total number of articles indexed in PubMed, it had a low number of PubMed publications relative to its GDP. Focusing on a subject area, Harande (2011) examined the increasing diabetes-related literature in Nigeria between 1996 and 2009, and analysed the list of periodicals to show a rapid expansion and growth in the publication of diabetes-related research in Nigeria. However, he suggested that more collaborative efforts needed to be exercised by medical doctors, health and allied workers to combat the menace of this disease. A very crucial aspect of this research relates to the sources through which researchers disseminated their work (Sweet et al. 2014).

RESEARCH METHODOLOGY

Scope of the study, population and sample

The study focuses on West Africa, a sub-region with an estimated population of 314 million (UNDESA 2011) and comprising sixteen countries (Benin, Burkina Faso, Cape Verde, Côte d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone, Togo). Fifteen of these countries (minus Mauritania) belong to the Economic Community of West African States (ECOWAS). This study covers top article-producing countries in the ECOWAS members of the sub-region. Data for the study spans 2005–14, a period selected to reflect the most current situation in biomedical research in the sub-region. This period has also seen serial conflicts in many of the countries: wars in Liberia, Côte d'Ivoire and Sierra Leone, and political and religious crisis in Mali and Nigeria. Conflicts disrupt peace and security, and often dismantle academic activities and dissemination of research.

Data were drawn from:

- MEDLINE/PubMed, a free online bibliographic database of the National Library of Medicine (NLM) in the US.
- The h-index and the number of citations of authors retrieved from Google Scholar. Google Scholar provides total citation count, total number of cited publications and Jorge E. Hirsch's index (h-index).
- The impact factors of the journals were retrieved from the SCImago Journal and Country Rank portal, that includes the journals and country scientific indicators developed from the information contained in the Scopus® database.

To retrieve the publications of authors from the various countries in MEDLINE/PubMed, the title field and the publication date field were combined. Names of the countries and dates of coverage of the study, namely 2005 and 2014, were entered into the title field of MEDLINE/PubMed. The search function looks thus: ("COUNTRY" [Title]) AND

("2005/01/01" [Date – Publication]: "2014/12/31" [Date – Publication]). For instance, to search for publications on Nigeria, the researcher merely used the following search function: (NIGERIA [Title]) AND ("2005/01/01"[Date – Publication]: "2014/12/31"[Date – Publication]). To obtain data from SCImago Journal and Country Rank, the names of the authors or journals, as the case may be, were entered into the websites.

Data management and analysis

First, data retrieved from all the fifteen countries was sorted according to their first authors, and thereafter entered into Microsoft Excel for further analysis. The initial result was displayed in frequency distributions, percentages and tables. Authors were listed and ranked according to the number of papers they produced and according to their impact factors.

Further analysis was carried out to measure productivity using LOTKA®, free online software designed by Rousseau and Rousseau in 2001. Rousseau and Rousseau's software follows Nicholls' methodology: organization of the data in a size-frequency form, using all the data without truncation, estimation using the maximum likelihood approach and then testing, performed using Kolmogorov-Smirnov test statistic. Lotka® compares the Kolmogorov-Smirnov (K-S) maximum difference statistic (|D-Max|) with the K-S table values at 0.01, 0.05 and 0.1 significance levels and given degrees of freedom. Productivity will not observe Lotka's distribution if (|D-Max|) < K-S value at the various levels of significance. It was considered necessary to adjust the number of publications per country by the population of the countries in order to make data management easier. This was obtained by taking the ratio of the number of publications by 100,000 populations.

Lawani (1980) introduced the collaboration index (CI) which he defined as the average number of authors per article. This index did not consider the effect of the single-authored articles in the index. A new index, namely degree of collaboration, was devised in 1983 by Subramanyam (1983). Subramanyam defined this index as the ratio of single-author articles to the total number of articles. This technique was also found to be deficient because it does not differentiate the multiple-author articles when the number of authors varies. In 1988, Ajiferuke, Burell and Tague introduced the collaborative coefficient (CC). CC works by conferring a ratio to 1/j to each paper with j being the number of authors; subtraction of the sum of the score of all articles from 1 makes the CC index (Tague, Burell and Ajiferuke 1988). They showed that the collaborative coefficient had the advantages of previous indices. This index differentiates various levels of multiple authorships. When single-author articles are in the majority, this index will trend toward zero. The collaborative coefficient (CC) is given as:

$$CC=\sum(1/j)P(X=j), \text{ where,}$$

X=number of authors, j=number of authors responsible for a paper during a certain period.

RESULT

General distribution of publications

A total of 4,946 unique authors were identified in the fifteen countries, and they produced 8,560 articles. Table 1 shows the number of publications per country per year for the fifteen ECOWAS member countries. Altogether, Nigeria produced 51.6 per cent of all

articles coming from the sub-region, thus making this the country with the highest number of publications, followed by Ghana with 13.7 per cent articles while Senegal had the third highest publications with 8.34 per cent. Burkina Faso, Mali and Gambia had 8.27, 5.43 and 2.43 per cent of articles respectively.

Table 1: Frequency distribution of publications per country per year

Countries	**Total no. of Publications (%)**	**No. of publications per year for the whole countries**									
		2005	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
Nigeria	4,479 (52.32)	265	247	291	360	399	493	563	651	665	766
Ghana	1,169 (13.66)	61	80	85	88	113	137	145	144	200	268
Senegal	714 (8.34)	57	57	48	79	67	70	85	99	88	101
Burkina Faso	708 (8.27)	43	55	46	47	70	89	88	100	113	105
Mali	465 (5.43)	29	23	32	50	44	70	55	58	69	68
Gambia	280 (3.27)	24	26	22	30	31	22	35	26	36	38
Togo	195 (2.28)	10	18	10	14	17	26	24	23	29	42
Côte d'Ivoire	159 (1.86)	18	20	21	10	17	14	15	20	16	17
Guinea Bissau	151 (1.76)	14	7	15	18	14	22	20	12	22	20
Sierra Leone	104 (1.21)_	9	6	7	11	8	12	8	9	17	21
Liberia	66 (0.77)	3	9	1	4	9	3	5	4	14	16
Cape Verde	42 (0.50)	3	1	2	7	3	5	0	3	6	15
Guinea Conakry	26 (0.30)	0	2	1	5	3	3	2	3	4	3
Benin	1 (0.01)	0	0	0	0	0	0	0	1	0	0
Niger Republic	1 (0.01)	0	0	0	0	1	0	0	0	0	0
Total	**8,560 (100)**	**536**	**551**	**581**	**723**	**796**	**966**	**1,045**	**1,153**	**1,279**	**1,480**

Benin Republic made a single unit contribution or 0.011 per cent of the sub-regional total. Contributions of forty-two and twenty-six or 0.54 and 0.3 per cent were made by Cape Verde and Guinea Conakry respectively.

In respect of publication per population, Figure 1 shows further that Gambia had the highest publications per population with about sixteen articles published for every 100,000 Gambians. Guinea Bissau had the next highest number of publications per population (ten articles per 1,000 population) followed by Senegal (six articles per 100,000 population). Ghana, Burkina Faso and Togo are fourth, fifth and sixth with about 5, 4 and 3 per cent respectively. Nigeria is located in eighth position with less than three papers per 100,000 persons.

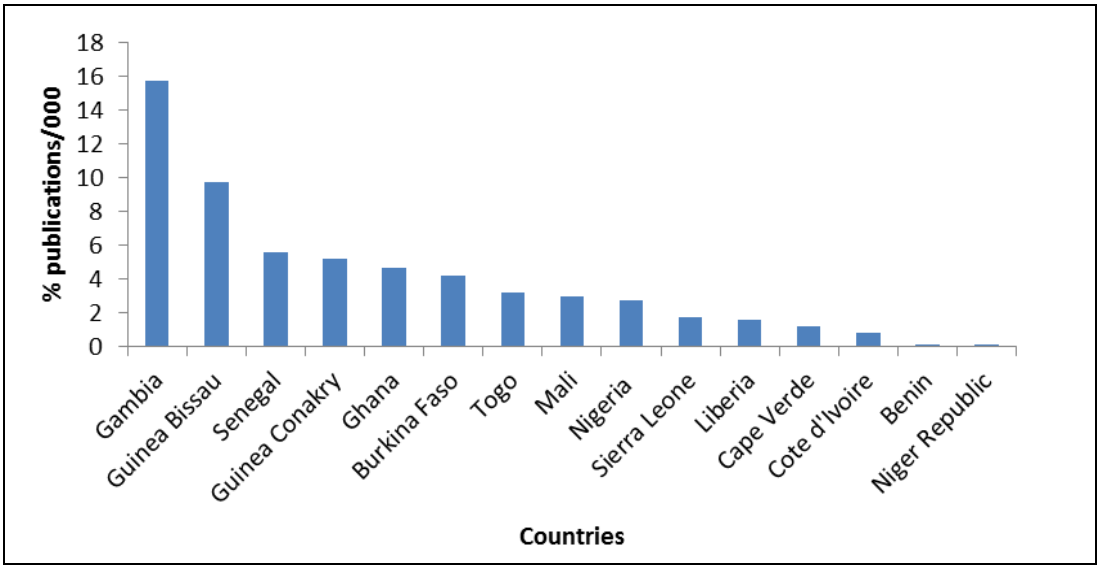

Figure 1: Publication/population (%/100,000)

Distribution of contributions by authors

Table 2 shows the distribution of papers by authors per country; that is the number of authors producing 1,2, 3... n papers. Considered together 69.12 per cent of the authors produced only one paper each. Only 15.12 per cent produced two papers each, while 14.09 per cent produced three papers each – the peak of the average of number of papers per author for the sub-region. A comparison across the countries shows some disparity. Côte d'Ivoire has the highest number proportion of authors (88.41 per cent) who produced only one paper during the period while Nigeria has the least (66.55 per cent). Furthermore, only one author in Nigeria – the highest producer and across the sub-region – was able to produce twenty-nine articles.

Specific country situations present some disparity. Table 2 shows further that for Nigeria, 67 per cent of the 2,398 scientists contributed just one article each while about 17 per cent contributed only two items each and about 8 per cent contributed three articles each. An estimated 8 per cent of the total authors made between four and nine contributions while approximately 1 per cent of the authors in the bibliography contributed at least ten items each. The total number of authors from Ghana was 767, constituting 15.5 per cent of the total authors in the study. About 78 per cent of the scientists in this country made just one contribution each while less than 13 per cent made two contributions each, and about 5 per cent made three contributions each. More than 4 per cent of the authors contributed between four and nine items. A total of 437 scientists contributed one or more articles in Senegal with about 72 per cent of the scientists producing one item each while about 14 per cent produced two items each, and more than 6 per cent produced three items each. About 7 per cent produced between four and ten items while less than 1 per cent produced at least ten items. It is observed from Table 3 that 418 scientists emanated from Burkina Faso. About 66.75 per cent of these scientists produced one item each while about 17.7 per cent produced two items each, and more 9 per cent produced three items each. About 6 per cent produced between four and ten articles while less than 1 per cent produced at least ten items while Mali had a total of 309 scientists producing one or more items. About 75 per cent produced one item each while less than 14 per cent produced two items each and three items were produced by more than 5 per cent of the scientists. More than 5 per cent of the scientist produced between four and ten articles.

Table 2: Distribution of papers by number of authors

No. of pape-rs	Nigeria		Ghana		Senegal		Burkina Faso		Mali		Gambia		Togo		Côte d'Ivoire		Guinea Bissau		Sierra Leone	
	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%	No. of authors	%
1	1,596	66.55	596	77.71	313	71.62	279	66.75	233	75.40	133	69.27	83	73.45	122	88.41	63	70.00	70	83.33
2	397	16.55	95	12.39	62	14.19	74	17.70	41	13.27	39	20.31	13	11.50	12	8.70	13	14.44	10	11.90
3	191	7.96	38	4.95	30	6.86	40	9.57	18	5.83	15	7.81	4	3.54	3	2.17	6	6.67	4	4.76
4	77	3.21	16	2.09	11	2.52	7	1.67	8	2.59	1	0.52	4	3.54	1	0.72	5	5.56	0	0.00
5	42	1.75	8	1.04	12	2.75	8	1.91	3	0.97	4	2.08	6	5.31	0	0.00	0	0.00	0	0.00
6	29	1.21	4	0.52	6	1.37	2	0.48	3	0.97	0	0.00	0	0.00	0	0.00	1	1.11	0	0.00
7	21	0.88	3	0.39	2	0.46	3	0.72	1	0.32	0	0.00	2	1.77	0	0.00	0	0.00	0	0.00
8	14	0.58	4	0.52	0	0.00	3	0.72	1	0.32	0	0.00	1	0.88	0	0.00	1	1.11	0	0.00
9	5	0.21	1	0.13	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	1	1.11	0	0.00
10	9	0.38	0	0.00	0	0.00	1	0.24	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
11	3	0.13	0	0.00	0	0.00	1	0.24	1	0.32	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
12	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
13	3	0.13	2	0.26	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
14	5	0.21	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
15	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
16	3	0.13	0	0.00	1	0.23	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
17	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
29	1	0.04	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00	0	0.00
Total	2,398	100	767	100	437	100	418	100	309	100	192	100	113	100	138	100	90	100	84	100

Scientific productivity

Table 3 contains results on productivity of the authors, using Lotka's statistics. The table shows the maximum differences (D-Max), the beta values (α) which indicate the level of productivity of authors, the C-Values (k) which indicate the number of authors making one contribution only, and Kolmogorov-Smirnov statistics indicating the significance of the test at 1, 5 and 10 per cent. The result indicates that α=2.33 for Nigeria, while its intercept (k) is 70.57 per cent. Compared with a theoretical threshold of α=2, the result suggests a low proportion of highly productive scientists in Nigeria and a high proportion of biomedical scientists with a single contribution (k=70.57 per cent). For Ghana, Table 3 further shows that the number of scientists that contributed just one item each is 78.83 per cent, and, α=2.72 also suggesting a low productivity of biomedical literature in Ghana.

Table 3: Scientific productivity of authors in selected African countries

Country	DMax	N	C-Value	Beta(α)	Kolmogorov-Smirnov statistics		
					1%	5%	10%
Côte d'Ivoire	1	138	0.000	1.260	0.139	0.116	0.104
Nigeria	0.040	2398	0.706	2.329	0.033	0.028	0.025
Burkina Faso	0.053	418	0.721	2.391	0.079	0.067	0.059
Guinea Bissau	0.028	90	0.728	2.422	0.172	0.143	0.129
Togo	0.034	113	0.735	2.453	0.153	0.128	0.115
Senegal	0.027	437	0.743	2.489	0.078	0.065	0.058
Sierra Leone	0.049	84	0.751	2.526	0.167	0.139	0.125
Gambia	0.066	192	0.759	2.564	0.118	0.098	0.088
Mali	0.019	309	0.773	2.636	0.093	0.077	0.069
Ghana	0.011	767	0.788	2.720	0.059	0.049	0.044

Prolific authors

Table 4 contains the list of the most prolific authors measured by absolute number of papers written by them, in addition to the Hirsh index and citation counts. It should be noted that the h-index represents the gross standing of the authors in terms of their productivity, and not only in respect of biomedical research. It could be observed that Nigeria dominated the list of ten most productive authors, producing nine authors while a Senegalese author is the tenth. Onwujekwe from Nigeria is the most productive biomedical author with twenty-nine publications, followed by Onyeaso, also from Nigeria with seventeen, and Ndiaye from Senegal with sixteen. Cadmus (16), Uneke (16), Oshikoya (16), Adewuya (14), Olusanya (14), Omokhodion (14) and Desalu (14) all from Nigeria completed the top ten positions.

Table 5 shows the top ten high-impact authors and their countries of origin in the selected countries measured by h-index, as at 2014. It is observed that Hill from Ghana had the highest h-index of 208 and received 52,443 citations while Roth from Guinea Bissau had h-index value of 146 and received 37,565 citations. Moore from Togo and Bowman from Gambia both had h-index values of 90 and 89, and received 92,669 and 34,216 citations respectively while Culp from Gambia, Adjei from Ghana and Aaby from Guinea Bissau are joint-tenth with h-index values of 58 each, and 20,933, 9,534 and 8,337 citations respectively.

Table 4: Top ten most productive authors in selected West African countries

Rank	Name of authors	No. of publications	H–index (all papers)	No. of citations	Country
1	Onwujekwe, O.	29	22	1,480	Nigeria
2	Onyeaso, C. O.	17	12	441	Nigeria
3	Ndiaye, P.	16	39	5,256	Senegal
4	Cadmus, S.I.	16	13	703	Nigeria
5	Uneke, C.J.	16	12	467	Nigeria
6	Oshikoya, K.A.	16	9	184	Nigeria
7	Adewuya, A.O.	14	19	930	Nigeria
8	Olusanya, B.O.	14	15	773	Nigeria
9	Omokhodion, F.	14	12	365	Nigeria
10	Desalu, O.O.	14	8	252	Nigeria

Table 5: Top ten high-impact authors in West Africa

Rank	Names of authors	Number. of publications	H-index in all papers	No. of citations for all papers	Country
1	Hill, Z.	7	208	52,443	Ghana
2	Roth, A.	4	146	37,565	Guinea Bissau
3	Moore, A. R.	5	90	92,669	Togo
4	Bowman, R.J.	3	89	34,216	Gambia
5	Burton, M.J.	5	80	38,667	Gambia
6	Fisher, T.K.	4	83	53,915	Guinea Bissau
7	Kirby, M.J.	5	78	34,429	Gambia
8	Hill, P.C.	5	77	61,629	Gambia
9	Muller, O.	7	70	13,279	Burkina Faso
10	Culp, K.	3	58	20933	Gambia
10	Adjei, A.A.	13	58	9534	Ghana
10	Aaby, P.	9	58	8337	Guinea Bissau

Ten most high-impact journals used by biomedical authors from West Africa

Table 6 presents the ten highest impact journals measured by impact factors; it also shows the number of articles published in the journals, the countries of origin of the authors and the countries of origin of the journals. It can be seen that *The Lancet*, a United Kingdom (UK)-based journal, is the most prestigious journal in which West African authors published their research. Authors from Sierra Leone and Gambia published six and five articles in *The Lancet* respectively. Burkina Faso and Guinea Bissau published eleven and six articles respectively in *Journal of Infectious Diseases*, which is the next high ranking journal of choice to West African authors; it has JIF of 0.831 and ranked second. The *AIDS* journal in the United States (US) has a JIF of 0.709 and two countries, Guinea Bissau and Gambia, published in it. While *PLoS One*, a US-based journal has a JIF of 0.519 and authors from three countries, namely Gambia, Mali and Guinea Bissau, published in it. Authors from Gambia, Guinea Bissau and Mali respectively published in *Emerging Infectious Diseases* (0.476), *Bulletin of the World Health Organisation* (0.428), *Euro Surveillance; Bulletin Européen sur les maladies*

transmissibles (European Communicable Disease Bulletin (0.375), *Vaccine* (0.369) and *PLoS Neglected Tropical Diseases* (0.362).

Table 6: Number of publications in the top ten journals by impact factor

Rank	Name of journal	SCIMago Journal Report	No. of publications	User countries	Journal's country of origin
1	*Lancet*	1.486	6 and 5	SL and GM	UK
2	*Journal of Infectious Diseases*	0.831	11and 6	BF and GW	US
3	*AIDS*	0.709	6 and 5	GW and GM	US
4	*International Journal of Epidemiology*	0.527	6	GW	UK
5	*PLoS One*	0.519	11, 8 and 7	GM, ML and GW	US
6	*Emerging Infectious Diseases*	0.476	16	SN	US
7	*Bulletin of the World Health Organisation*	0.428	6	GM	Switzerland
8	*Euro Surveillance; Bulletin Européen sur les maladies transmissibles (European Communicable Disease Bulletin)*	0.375	5	GM	France
9	*Vaccine*	0.369	9	GW	Netherlands
10	*PLoS Neglected Tropical Diseases*	0.362	9	ML	US

Key: GW= Guinea Bissau, ML= Mali, BF= Burkina Faso, GM= Gambia, SL= Sierra Leone, SN= Senegal.

It could also be observed that among the ten countries in the study, Guinea Bissau and Gambia both had the widest spread of their papers, publishing in five of the top ten journals, Mali published in two while Sierra Leone, Burkina Faso and Senegal published in one journal each. Five of the ten journals originated from the US while two originated from the UK and the remaining were from Switzerland, France and the Netherlands. The most populous countries, namely Nigeria and Ghana, are absent in the list of users of the top ten high-impact factors journals in which West African authors published.

Most popular journals by country

Table 7 presents the frequency distribution of the ten most popular journals used by authors in the countries assessed by number of publications and by the number of countries publishing in the journals. The top ten journals accounted for 1,006 or about 12 per cent of the 8,424 publications emanating from the ten countries in the sub-region. Six of the journals, *Plos One*, *Transactions of the Royal Society of Tropical Medicine*, *American Journal of Tropical Medicine*, *Malaria Journal*, *Tropical Medicine and International Health* and *West African Journal of Medicine*, were English and they originated from UK, US and Nigeria while the other four were French. Only one of the journals, *West African Journal of Medicine* based in Nigeria, originated from a country in the sub-region. A French journal, *Medicine Tropicale* published 196 papers, the highest number of papers published in a single journal by scholars in the sub-region – French is the dominant language of the sub-region.

Table 7: Top ten most popular journals in West Africa

Rank	Journals	GW	GH	SN	BF	ML	GM	TG	CI	NG	SL	NoC	TNoP
1	*Medecine Tropicale*	0	0	82	27	23		38	26	0	0	5	196
2	*West African Journal of Medicine*	0	21	0	0	0	0	0	0	164	0	2	185
3	*Tropical Medicine and International Health*	6	51	12	42	9	12	0	0	0	3	7	135
4	*Bulletin de la Société de Pathologie Exotique*	0	0	41	35	18	0	10	11	0	0	5	115

5	*Malaria Journal*	0	29	26	27	19	10	0	0	0	3	6	114
6	*American Journal of Tropical Medicine and Hygiene*	0	34	12	15	21	7	4	0	0	2	7	95
7	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	5	29	15	0	0	8	0	0	0	4	5	61
8	*Sante*	0	0	15	31	0	0	11	0	0	0	3	57
9	*PloS One*	7	0	0	0	8	11	0	0	0	0	3	26
10	*Médecine et Maladies Infectieuses*	0	0	11	0	0	0	6	5	0	0	3	22

Key: GW=Guinea Bissau, GH=Ghana, SN=Senegal, BF=Burkina Faso, ML=Mali, GM=Gambia, TG=Togo, CI=Côte d'Ivoire, NG=Nigeria, SL=Sierra Leone, NoC=number of citations; TNoP=total number of publications.

This number of papers was contributed by authors from five countries: Senegal, Burkina Faso, Mali, Togo and Côte d'Ivoire. Nigerian authors published their largest number of papers in the *West African Journal of Medicine*, hosted in Nigeria. As would be expected, authors from English-speaking countries published in only English journals but authors from French-speaking countries published mainly in French journals. It could be observed that some of the French-speaking countries such as Senegal, Burkina Faso and Mali published articles in English journals such as *Tropical Medicine and International Health* and *Malaria Journal.* On the contrary, only authors from Togo put seventeen articles in two French journals; other English-speaking countries such as Nigeria, Gambia and Ghana published strictly in English journals.

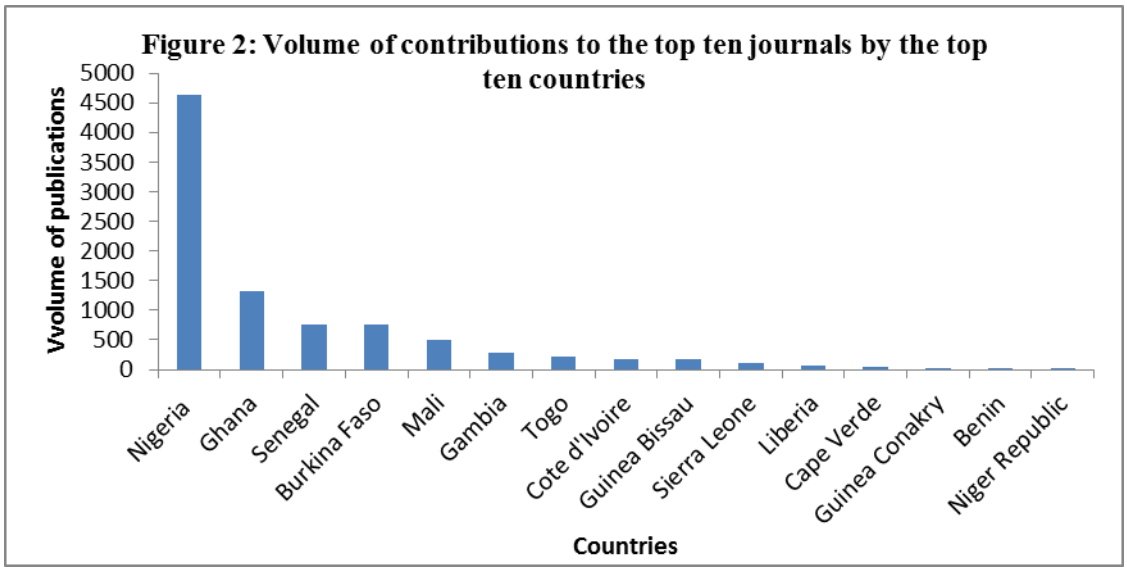

Figure 2: Volume of contributions to the top ten journals by top ten countries

In terms of spread, the French-speaking countries distributed their papers among the top ten journals including English journals. For example Senegal and Burkina Faso distributed their papers among eight and six of the ten journals respectively, including in English journals; all Nigeria's papers were channelled only to one journal; Ghana spread its papers across five journals but they were all English journals. This might explain why the French-speaking countries have the highest number of papers in the top ten journals, with Senegal leading with 214 papers while Burkina Faso follows with 177.

Most popular journals – a country-by-country analysis

A country-by-country analysis of the top ten channels through which the researchers published articles in the various countries presents an interesting result (see Appendices 1–10). Appendix 1 shows that biomedical researchers from Guinea Bissau did not publish in any journal in their country, nor did they publish in any journals of African origin. Rather, they published in five journals in the UK, four in the US and one in the Netherlands. The mean impact factor of the journals in which the scholars published is 0.41. Guinea Bissau scholars also published in *PloS One*, a frontline open access channel.

A single Ghanaian journal *Ghana Medical Journal* whose impact is not listed in SJR was the major channel of Ghanaian biomedical research; biomedical scholars from Ghana also published in two journals that originated from Nigeria: *African Journal of Reproductive Health*, *West African Journal of Medicine*, and a Kenya-based journal *East African Medical Journal.* Bedsides the Ghanaian journal, the three African journals where Ghanaian scholars published had the lowest impact factors in SJR. Four of the Ghanaian scholars' choice journals originated from the UK while one journal each from the US and the Netherlands were also used to disseminate their research findings. The mean impact factor of journals in which Ghanaian scholars published is 0.136. As at 2011, none of the choice journals of Ghanaian biomedical researchers were available as open access channels (see Appendix 2).

A Senegalese journal *Dakar Medical* was the only journal of African origin where scholars from Senegal published their research papers. Although Senegal is a French-speaking country, five of the journals in which Senegalese scholars published were English; other papers were spread across German, Dutch and French journals. The journals in which Senegalese scholars published have a mean of 0.157. None of the journals was an open access journal (see Appendix 3).

Scholars from Burkina Faso, a French-speaking country, published in six English journals located in the US, UK and the Netherlands. The other channels were located in Belgium, France, Pakistan and Germany. Burkinabe scholars neither published in a journal in Burkina Faso nor in any other African country. With an overall mean impact factor of 0.206, none of the journals is open access (see Appendix 4).

Malian scholars have similar publishing characteristics with those in Burkina Faso. Though a French speaking country, six of the top ten journals in which they published were English while the rest came from Belgium, the Netherlands and Germany. Unlike other countries in this analysis, a Malian journal *Mali Medical* was the major channel of disseminating Malian medical research papers, although the journal's impact factor is not listed in SJR. The overall mean impact factor of the top ten journals of choice of Malian scholars is 0.190 (see Appendix 5). Eight of the ten choice journals of biomedical researchers from the Gambia were English journals originating from the UK, US and Switzerland. The researchers did not publish in any Gambian journal or in any other African journal. Altogether, the top ten journals have a mean impact of 0.460, and one of the journals is open access (see Appendix 6). Gambia is the only country among the top ten in which *Plos One*, an open access journal, is listed.

Togo is an English-speaking country, and four of the ten top journals used by scholars from this country are French, based in Mali, Belgium, the Netherlands and France. Indeed, a French journal, *Medecine Tropicaine* constituted a major channel for Togolese scholars. Unlike Burkina Faso, Togolese scholars published in a Malian journal. The mean of the journals is as low as 0.099 (see Appendix 7). Of all the French-speaking countries in the sub-region, Côte d'Ivoire published in more French journals than the others – six, altogether – based in Senegal, France, Belgium, Germany and

the Netherlands. The Senegalese journal in the list, *Odontostomatol Tropicale,* did not have any impact factor listed in SJR. The mean of the impact factors of the journals is 0.112. Just like Burkina Faso, Senegalese researchers did not publish in any African journal, except based in Senegal; none of the top ten journals of Senegalese scholars' choice is open access (see Appendix 8).

More than scholars in any other West African country, six of the top ten journals in which Nigerian scholars published were Nigerian in origin. They also published in another African channel, namely the Ugandan-based *African Health Sciences Journal*. All the journals in which these scholars published their papers were English. The predominantly local focus in choice of channels probably accounted for a low mean impact factor of 0.049; the journals were also not open access (see Appendix 9). None of the top ten journals of choice of Sierra Leonean authors (mean impact factor=0.333) were either based in Sierra Leone or in a language other than English. Sierra Leonean researchers did not find spaces in Nigerian, or any other African journals (see Appendix 10).

Co-authorship and collaboration

Table 8 shows that the collaborative coefficient (CC) of Nigerian biomedical authors was on the increase, as it rose from 0.523 in 2005 to 0.601 in 2008, after which it dropped to 0.599 in 2006. CC increased again from 0.599 to 0.656 between 2009 and 2010 and finally dropped in 2014. Collaboration was highest in 2013 when a CC value of 0.656 was recorded. Collaboration in Ghana was rather unstable during the period, evident in the variations in its CC values. However, its collaboration reached a peak when it recorded a CC value of 0.702 in 2014. Senegal also had similar variations in collaboration as Ghana having up and down movements in CC values between 2005 and 2012, after which there was increase in 2013 and 2014. It is also observed that the remaining countries had varied CC values through the ten years in view therefore indicating instability in the rate of collaboration in these affected countries.

Table 8: Collaborative coefficients of countries

Year	Nigeria	Ghana	Senegal	Burkina Faso	Mali	Gambia	Togo	Côte d'Ivoire	Guinea Bissau	Sierra Leone
2005	0.523	0.617	0.732	0.762	0.813	0.775	0.687	0.765	0.848	0.431
2006	0.535	0.543	0.800	0.766	0.689	0.769	0.758	0.661	0.721	0.644
2007	0.560	0.590	0.790	0.746	0.746	0.780	0.728	0.833	0.843	0.549
2008	0.601	0.652	0.770	0.978	0.782	0.760	0.655	0.836	0.767	0.598
2009	0.599	0.660	0.798	0.776	0.815	0.751	0.705	0.788	0.804	0.726
2010	0.603	0.658	0.757	0.770	0.709	0.753	0.784	0.777	0.759	0.519
2011	0.618	0.664	0.746	0.791	0.793	0.770	0.774	0.865	0.743	0.681
2012	0.627	0.636	0.796	0.825	0.851	0.813	0.782	0.743	0.847	0.734
2013	0.656	0.689	0.802	0.793	0.812	0.788	0.839	0.770	0.816	0.586
2014	0.630	0.702	0.814	0.796	0.797	0.832	0.766	0.841	0.838	0.654

Generally, Burkina Faso recorded the highest CC of 0.9796 in 2008 followed by Mali with 0.851 in 2010, and Guinea Bissau with 0.848 in 2005. Sierra Leone, on the other hand, had the lowest CC, 0.431, in 2005.

DISCUSSION OF FINDINGS

This study was designed to determine the quantity, impact, publication channels and collaborative evidence in biomedical literature in top-producing countries in West Africa during 2005–14. Nigeria, Ghana, Senegal, Burkina Faso and Mali occupied the first five positions in population size and number of publications. A small country, Gambia, eighth in terms of population, emerged sixth in

terms of publication production ahead of Côte d'Ivoire, Togo, Sierra Leone and Guinea Bissau. Gambia also emerged as the most productive in terms of normalized production with sixteen out of every 100,000 person publishing biomedical literature while Guinea Bissau came second with ten out of every 100,000 persons publishing, and Senegal came third with six out of every 100,000 persons producing biomedical articles. Uthman (2010) noted in his study that Gambia and Guinea Bissau were the most productive countries when the total products were normalized by number of people with HIV. Uthman and Uthman (2007) also observed that Gambia had the best research performances based on the number of research articles per million inhabitants and research articles per GDP. These observations could be as a result of strong and sound policies, political stability, and the availability of funds for researchers from this country.

Based on the raw data, Nigeria recorded growth in the production of biomedical articles between 2003 and 2011 while Burkina Faso also registered significant growths between 2004 and 2011. Other countries except Ghana had unstable growths in the number of publications they produced. Tijssen (2007) believed that these growths could be as a result of the availability of electronic online submission systems that made it easier for African authors to submit their studies. Over 70 per cent of all the biomedical authors produced an article each while about 29 per cent produced between two and ten articles, and less than 1 per cent of the authors produced above twenty articles. This implies that articles written by one author are more in number than those produced by two or more authors.

The scientific productivity of biomedical authors according to Lotka's analyses showed that apart from Côte d'Ivoire that had an α value of less than 2, all other countries had an α value greater than 2 which does not correspond with Lotka's benchmark of $\alpha=2$. This indicates the authors in these countries are less productive, and it can be said therefore that there is a very low proportion of highly productive biomedical literature in West Africa.

Aside from Senegal's Ndiaye who was the third most productive author with sixteen articles, Nigerian authors occupied the remaining nine positions. The implication of this is that Nigerian authors were the most productive in terms of number of publications produced. This is so because of there are lots of scholars who are in biomedical research, and also, because of the establishment of research institutions owned by both private and government bodies established over recent years to tackle both health and environmental issues encountered in the country.

Hill from Ghana is the most impactful author in West African biomedicine followed by Guinea Bissau's Roth and Togo's Moore. None of Nigeria's authors made the top ten most impactful author rankings. One possible reason could be that most, if not all, of the biomedical articles produced by Nigerian authors were published in local (national) or regional journals which have low or no impact factors. Out of all the valid documents analysed, 9.5 per cent were written by single authors while 90.5 per cent were written by two or more authors. It can therefore be concluded that the trend of collaboration among biomedical authors was very high in these selected countries. The possible explanation for the consistent increase observed in publication output of researchers may be due to the efforts being put into scholarly publication for visibility among peers and career advancement (Ajao and Lawoyin 2005). Another reason could be the need for scientists from different areas of expertise to come together to address problems using different approaches, methods and perspectives.

Sierra Leone, Gambia, and Guinea Bissau, all ranked below the top five in terms of population size and article production, published more in journals with high impact factors. Only Burkina Faso, Senegal and Mali ranked among the top five countries in terms of population and publication

distribution featured in the journals with high impact factors. It is obvious that most of the West African countries published in journal located abroad, either in the US or Europe. Nigeria on the other hand is missing out because a very large percentage of its biomedical literatures were published locally i.e. in journals located in Nigeria that have no or low impact factors.

The only journal of West Africa origin, *West African Journal of Medicine*, in the top ten journals in which authors from the sub-region published, ranked tenth. This result points to a recurring observation that most African scholars prefer or are compelled by either lack of reputable sources at home or institutional policies to publish their findings in journals located in the developed world. This behaviour is further promoted by common notions of the low quality of African local journals as well as the research evaluation methodology which recommends that researchers should publish their research abroad in order to gain visibility.

Despite policies in the university system requiring researchers to publish abroad (Adomi and Mordi 2003), Nigerian researchers appear to prefer journals emanating from their country. Basically, medicine is largely a local discipline, often addressing challenges that exist in the immediate environment. It would appear that these researchers are naturally responding to the needs of the local and immediate community. The relatively larger research infrastructure or large number of universities and research institutes in these countries by comparison with others could translate into greater confidence in their local journals as channels of disseminating research findings. Furthermore, readership audiences in these countries are also considerably large enough to sustain journals. This may not be the same as with smaller countries whose audience might be relatively too small to market research journals.

What could one make out of the fractional mean impact factors of the journals used by the researchers in this study? The big countries namely Nigeria and Ghana which published much of their research in their local journals have very small mean impact factors while smaller countries such as Sierra Leone have a larger mean impact factor. A common stereotype, that fewer English speakers speak French in comparison with French speakers that speak English, played out in this study. More French-speaking countries produced researchers that published in English journals than English researchers that published in French journals.

It is interesting to notice that except Sierra Leone, those countries in the sub-region that have encountered the most conflicts still fall into the top ten countries in terms of paper production. It may be that scholars who were displaced wrote papers from their locations in the names of their local institutions. Basically, the relatively larger population of Nigeria and the sectional nature of the conflicts in areas that produce research papers the least in the country (Nwagwu, in peer review) might provide some explanation. This explanation does not however suffice for the other countries which are small in size but are in the top ten producing countries. It can be inferred therefore that the paper production in the sub-region and in these conflict-afflicted countries would have been much higher in the absence of any conflicts.

CONCLUSIONS, RECOMMENDATIONS AND LIMITATIONS

Nigerian authors outranked authors from other countries in terms of volume of publications, but none of Nigeria's prolific authors appeared in the list of the most impactful authors. It is also significant that the most impactful authors did not appear in the list of authors that produced the largest volumes of papers. While the most prolific author produced twenty-nine papers (Table 4), the most impactful author produced only seven papers (Table 5). Nigerian authors published mainly

in Nigerian local journals; for this reason their impact was lower than authors from other countries who published in journals outside their countries, and outside Africa. Nigeria and Ghana did not appear in the top ten most impactful journals that published papers written by West African authors. It would appear that smaller countries in the sub-region target high impact factor journals, while the big ones prefer the other category of journals. This could be explained by the further finding in this study that Nigerian and Ghanaian authors published in Nigerian local journals more than authors from any other country published in their own local journals.

Some recommendations emanate from the results presented in this article. Countries in the sub-region should implement science policies that apply performance appraisal approaches that prioritize quality and collaboration within and outside the country. There should be projects with policies geared towards strengthening local journals sources, strengthening the peer review mechanism of journals and collaboration. Also, with the advantage of huge resources, and differentials in publications evidence, Nigeria should provide leadership in the region by providing collaborative assistance to scholars from other countries. Bibliometric studies are fraught with several limitations particularly in Africa. The source of the data is not comprehensive mainly because there are no local sources that index local publications; also there is the possibility of the search scheme omitting some of the publications in some countries due among other reasons to differences in language.

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Appendix 1: Top ten journals in Guinea Bissau

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Vaccine*	9	0.369	Netherlands
2	*Pediatric Infectious Disease Journal*	8	0.319	US
3	*PLoS One*	7	0.519	US
4	*Acta Paediatrica, International Journal of Paediatrics*	6	0.128	UK
5	*AIDS*	6	0.709	US
6	*International Journal of Epidemiology*	6	0.527	UK
7	*Journal of Infectious Diseases*	6	0.831	US
8	*Tropical Medicine and International Health*	6	0.241	UK
9	*British Medical Journal*	5	0.320	UK
10	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	5	0.192	UK

Appendix 2: Top ten journals in Ghana

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Ghana Medical Journal*	73		Ghana
2	*Tropical Medicine and International Health*	51	0.241	UK
3	*American Journal of Tropical Medicine and Hygiene*	34	0.209	US
4	*Malaria Journal*	29	0.276	UK
5	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	29	0.192	UK
6	*African Journal of Reproductive Health*	22	0.041	Nigeria
7	*West African Journal of Medicine*	21	0.032	Nigeria
8	*Environmental Monitoring and Assessment*	20	0.056	Netherlands
9	*East African Medical Journal*	17	0.051	Kenya
10	*BJOG: An International Journal of Obstetrics and Gynaecology*	17	0.268	UK

Appendix 3: Top ten journals in Senegal

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Medecine Tropicale*	82	0.041	Belgium
2	*Bulletin de la Société de Pathologie Exotique*	41	0.041	Germany
3	*Dakar Medical*	36		Senegal
4	*Malaria Journal*	26	0.276	UK
5	*Emerging Infectious Diseases*	16	0.476	US
6	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	15	0.192	UK
7	*Santé (Montrouge, France)*	15	0.036	France
8	*American Journal of Tropical Medicine and Hygiene*	12	0.209	US

9	*Tropical Medicine and International Health*	12	0.241	UK
10	*Medecine et Maladies Infectieuses*	11	0.065	Netherlands

Appendix 4: Top ten journals in Burkina Faso

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Tropical Medicine and International Health*	42	0.241	UK
2	*Bulletin de la Société de Pathologie Exotique*	35	0.041	Germany
3	*Santé (Montrouge, France)*	31	0.036	France
4	*Malaria Journal*	27	0.276	UK
5	*Medecine Tropicale*	27	0.041	Belgium
6	*Pakistan Journal of Biological Sciences*	19	0.042	Pakistan
7	*American Journal of Tropical Medicine and Hygiene*	15	0.209	US
8	*Social Science and Medicine*	15	0.152	Netherlands
9	*Journal of Infectious Diseases*	11	0.831	US
10	*Journal of Medical Virology*	11	0.267	US

Appendix 5: Top ten journals in Mali

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Mali Medical*	46		Mali
2	*Medecine Tropicale*	23	0.041	Belgium
3	*American Journal of Tropical Medicine and Hygiene*	21	0.209	US
4	*Malaria Journal*	19	0.276	UK
5	*Bulletin de la Société de Pathologie Exotique*	18	0.041	Germany
6	*Acta Tropica*	13	0.168	Netherlands
7	*PLoS Neglected Tropical Diseases*	9	0.362	US
8	*Tropical Medicine and International Health*	9	0.241	UK
9	*PLoS One*	8	0.519	US
10	*Journal of Ethnopharmacology*	7	0.114	Netherlands

Appendix 6: Top ten journals in Gambia

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*International Journal of Tuberculosis and Lung Disease*	13	0.249	France
2	*Tropical Medicine and International Health*	12	0.241	UK
3	*PLoS One*	11	0.519	US
4	*Malaria Journal*	10	0.276	UK
5	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	8	0.192	UK
6	*American Journal of Tropical Medicine and Hygiene*	7	0.209	US
7	*Bulletin of the World Health Organization*	6	0.428	Switzerland
8	*AIDS*	5	0.709	US

9	*Euro surveillance: bulletin européen sur les maladies transmissibles (European communicable disease bulletin)*	5	0.375	France
10	*Lancet, The*	5	1.486	UK

Appendix 7: Top ten journals in Togo

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Medecine Tropicale*	38	0.041	Belgium
2	*Archives of Pediatrics and Adolescent Medicine*	17	0.275	US
3	*Santé (Montrouge, France)*	11	0.036	France
4	*Bulletin de la Société de Pathologie Exotique*	10	0.041	Germany
5	*Mali Medical*	6		Mali
6	*Medecine et Maladies Infectieuses*	6	0.065	Netherlands
7	*American Journal of Tropical Medicine and Hygiene*	4	0.209	US
8	*Archives of Virology*	3	0.162	Germany
9	*International Journal of Dermatology*	3	0.097	UK
10	*Transfusion Clinique et Biologique*	3	0.073	Netherlands

Appendix 8: Top ten journals in Côte d'Ivoire

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Medecine Tropicale*	26	0.041	Belgium
2	*Bulletin de la Société de Pathologie Exotique*	11	0.041	Germany
3	*Archives of Pediatrics and Adolescent Medicine*	7	0.275	US
4	*Odontostomatol Tropicale*	6		Senegal
5	*Parasite*	6	0.133	France
6	*Medecine et Maladies Infectieuses*	5	0.065	Netherlands
7	*American Journal of Physical Anthropology*	3	0.135	US
8	*Clinical Microbiology and Infection*	3	0.32	UK
9	*Revue d'Epidémiologie et de Santé Publique*	3	0.078	France
10	*Revue de Pneumologie Clinique*	3	0.034	France

Appendix 9: Top ten journals in Nigeria

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Nigerian Journal of Medicine*	275	0.043	Nigeria
2	*Nigerian Journal of Clinical Practice*	207	0.038	Nigeria
3	*Nigerian Postgraduate Medical Journal, The*	192	0.036	Nigeria
4	*African Journal of Medicine and Medical Sciences*	182	0.034	Nigeria
5	*West African Journal of Medicine*	164	0.032	Nigeria
6	*Journal of Obstetrics and Gynaecology Canada*	136	0.088	Canada
7	*African Journal of Reproductive Health*	118	0.041	Nigeria
8	*Annals of African Medicine*	111	0.061	Nigeria
9	*Tropical Doctor*	103	0.061	UK
10	*African Health Sciences*	77	0.061	Uganda

Appendix 10: Top ten journals in Sierra Leone

Rank	Name of journal	No. of publications	SJR	Country of origin
1	*Lancet, The*	6	1.486	UK
2	*Transactions of the Royal Society of Tropical Medicine and Hygiene*	4	0.192	UK
3	*World Journal of Surgery*	4	0.196	Germany
4	*British Medical Journal*	3	0.32	UK
5	*Journal of Infection*	3	0.293	UK
6	*Malaria Journal*	3	0.276	UK
7	*Tropical Medicine and International Health*	3	0.241	UK
8	*American Journal of Tropical Medicine and Hygiene*	2	0.209	US
9	*Curationist*	2	0.028	South Africa
10	*Disasters*	2	0.061	UK