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RESEARCH PAPER

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Mapping the global research output on Ebola vaccine from research indexed in web of science and scopus: a comprehensive bibliometric analysis

Tosin Yinka Akintunde[a,b,c], Taha Hussein Musa[c,d,e], Hassan Hussein Musa[f], Shaojun Chen[a], Elhakim Ibrahim[g], Sayibu Muhideen[h], and Joseph Kawuki[i]

[a]Department of Sociology, School of Public Administration, Hohai University, Nanjing, China; [b]Department of Demography and Social Statistics, Obafemi Awolowo University, Nigeria; [c]Organization of African Academic Doctor (OAAD), Nairobi, Kenya; [d]Key Laboratory of Environmental Medicine Engineering, Ministry of Education; Department of Epidemiology and Health Statistics, School of Public Health, Southeast University, Nanjing, China; [e]Biomedical Research Institute, Darfur University College, Nyala, Sudan; [f]Department of Medical Microbiology, Faculty of Medical Laboratory Sciences, University of Khartoum, Khartoum, Sudan; [g]Department of Demography, College for Health, Community and Policy, The University of Texas at San Antonio, San Antonio, Texas, USA; [h]Department of Philosophy of Science and Technology, University of Science and Technology of China, Hefei, China; [i]Centre for Health Behaviours Research, Jockey Club School of Public Health and Primary Care, The Chinese University of Hong Kong, China, Hong Kong

ABSTRACT

Introduction: The Ebola Virus outbreak in Africa is believed to be one of the deadliest viral infections that causes severe hemorrhagic fever in human and nonhuman primates, which has resulted in increased mortality rates in the affected African countries. Thus, the current study mapped and quantified global research output and trends in the EBOV vaccine publications via a bibliometric analysis.

Methods: Publications about the Ebola virus vaccine were extracted from the Web of Science and Scopus databases. HistCite, Bibliometrix, an R package, and VOSviewer.Var1.6.6 were used for data mapping and analysis.

Results: A total of 541 (WoS) and 511 (Scopus) documents were included, with a cumulation of 24,611 citations in both databases. These documents were published in 141 journals in the Wos and 185 in Scopus. The USA was the most productive country with 206 (38.08%) publications in the Wos. Although the top-cited authors are from the USA, the United Kingdom, and Canada, only one author from Africa "Samai M" from the University of Sierra Leone contributed 13 publications. Meanwhile, the *Journal of Infectious Diseases* was the most productive (45, 8.32%) in this field.

Conclusion: The study provides insight for researchers and health policy on the trends and progress of the EBOV vaccine research and development, focusing on the hot topics, research collaboration, and research dearth that requires urgent redress to fast-track an all-inclusive EBOV vaccine development.

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Introduction

The enormity of the Ebola Virus (EBOV) epidemic in Africa caused global panic as it was feared to escalate into a pandemic. The transmission and treatment option mode remains a global burden that consistently requires urgent policy and research mediation.[1] Thus, global unity was evident in the international collaboration to put the outbreak under control, which produced a remarkable result as evidenced by the World Health Organization's intervention (WHO), healthcare practitioners, and extensive research.[2] While global intervention has entailed combating EBOV, the investigation conducted on the genomes of EBOV revealed that its species exist in five forms with geographical peculiarities, such as Sudan ebolavirus (SEBOV) and Zaire ebolavirus (ZEBOV).[3] Others are the Bundibugyo ebolavirus (BEBOV), Cote d'Ivoire ebolavirus (CEBOV), and Reston ebolavirus (REBOV). Although no substantial evidence has been reported on the airborne potentiality of the human body, physical contact with carrier animals, an infected person alive or diseased has been a significant threat. The interaction of the virus with the human body and transmission mode can cause death to its host.[4] It becomes imperative that continuous effort be made to find a lasting solution to EBOV.

More recently, clusters of EBOV disease cases were reported in Guinea, with four infected persons declared dead, which raised significant concern if another species have just reemerged.[5] With the total global death rate that has been attributed to Ebola, the virus still has serious potential to increase global mortality. The international evidence of the average case fatality rate of EBOV is currently estimated at 50%, fluctuating from 25% to 90% over series of outbreaks.[6,7] Over the EBOV outbreak, there were 28,639 cases and 11,316 deaths reported between 2014 and 2016,[4] and the currently reported outbreak in the Democratic Republic of Congo (DRC) is the second-largest outbreak since the outbreak of Sierra Leone, and the present DRC outbreak has a record of 3317 cases and 2268 deaths as of 31 May 2021.[8]

While the world tries to bring COVID-19 infection to a halt, the world cannot afford a global outbreak of another deadly

CONTACT Hassan Hussein Musa hassantahir70@hotmail.com Department of Medical Microbiology, Faculty of Medical Laboratory Sciences, University of Khartoum, Khartoum, Sudan; Tosin Yinka Akintunde akintunde_olayinka@yahoo.com Department of Sociology, School of Public Administration, Hohai University, Nanjing, China

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virus that EBOV can be, given that there is a risk of reemergence in already plagued countries.[9] Although there are clinical treatment options available for EBOV,[10] the rapidity of its impact on the host body requires that the human body be resistant through the development of the vaccine. Hence, it is vital to ensure that the most susceptible population is vaccinated against the virus.

The development of the EBOV vaccine is crucial to the progress of fighting the virus. There is, however, remarkable clinical progress in the development of a recently approved vaccine. The EBOV (*Zaire ebolavirus*) vaccine is a replication-competent approved in December 2019, known as rVSVΔG-ZEBOV-GP Ebola vaccine (brand name Ervebo®) and manufactured by Merck is the only known vaccine and does not protect against other Ebola species.[11] The limitation of not having an EBOV vaccine for all species and the viruses' mutation ability is a global and public health concern. Therefore, while acknowledging that there is a worldwide effort to produce EBOV vaccine to safeguard people from infection, it is essential to examine various research efforts, thematic analysis of popular keywords, and top country contributors to EBOV vaccine research and identify potential research shortage and global representation.

In effect, a bibliometric analysis, an approach that explored metrics and information was adopted for mapping to provide accountability for research trends and themes in EBOV vaccine research. As a bibliometric analytical tool is an emerging research approach, numerous researchers have adopted the method of adjudicating different topics.[11–15] The current study on the EBOV vaccine's bibliometric analysis is to peruse research advances, account for progress and achievements, and provide policymakers and researchers research evidence and potential policy redress. The analytical output in this study may also expose the geographical non-representation toward EBOV vaccine research contribution. While EBOV remains a global threat, adopting different research methods is essential to support current evidence and usher in future policy frameworks and research.

Methods

Study design and data sources

The study adopted a statistical bibliometric analysis method to map the global research output of the EBOV vaccine. The current study focused on publications on the Web of Science (WoS) and Scopus databases. The WoS and Scopus are scholarly accessible platforms that host international publishing journals for researchers and scientists, hence no ethical approval was required for data extraction, analysis, and research presentation.

Search strategy and data extraction

The document retrieval was restricted to the terms and keywords like: "Ebola Vaccine," "Ebola Virus Disease Vaccine," "Ebola Vaccine," and "ebolavirus Vaccine," from the web of Science on 03 March, 2021. The documents' screening was based on the "Title" occurrence of the keywords to improve the search quality. In addition, articles that are "Original Research Article or Review Articles" were considered for data analysis.

Data analysis

Bibliometric analysis software includes HistCite,[16] Bibliometrix, an R package,[17] and VOSviewerVar1.6.6 (Leiden University, Leiden, The Netherlands) tool (https://www.vosviewer.com) was used for constructing and visualizing bibliometric networks to understand citation relationships and analyze the trend of publication over time.[18] Bibliometric analysis of qualitative analysis was presented as median and quartile range, and analysis was performed using GraphPad Prism 5.0 software. The correlation between the citations and study variables were calculated using the Spearman correlation coefficient. *P*-values less than 0.05 were considered statistically significant.

Results

Characteristic of the metadata

Approximately 541 (WoS) and 511 (Scopus) documents were retrieved. Papers in the Wos were published in 141 journal sources, and Scopus 185 journal sources contributed by 50 (Wos) and 55 (Scopus) countries, and 528 (Wos) and (160 Scopus) organization-enhanced research in the Ebola vaccine. The research collaboration index shows that Wos had 5.57 and Scopus 5.5 (Table 1).

The annual global trend of publications

The search outcomes of annual global trends and citation scores are shown in (Figure 1 (A and B)). About 541 (Wos) and 511 (Scopus) documents met the search criteria. The trends in EBOV vaccine research indicate that it is rapidly gaining prominence based on the recent outbreaks. The publication resources in both databases begin to rise from around 2012 and peaked in 2015.

Top 10 most cited documents

The top 10 most cited documents on the Ebola vaccine are presented in Table 2. This exposition supports the understanding of EBOV Vaccine research that gained massive attention from researchers. There is consistency in both databases on the top-cited articles on EBOV vaccine research as evident in the first four articles. The first document was published in Nature by Sullivan NJ, (2000) under the title "Development of a preventive vaccine for Ebola virus infection in primates,"[19] received a score of 509 citations. The second and third most cited documents in both databases were articles focusing on the efficacy and effectiveness of an rVSV-vectored vaccine[20] and "Live attenuated recombinant vaccine that protects nonhuman primates against Ebola and Marburg viruses."[21]

Table 1. Characteristics of the metadata of Ebola vaccine.

Description(WoS)	Results	(Scopus)	Results
Timespan	1980:2020	Timespan	1980:2020
Sources (Journals, Books, etc)	141	Sources (Journals, Books, etc)	185
Countries or origin	50	Countries or origin	55
Organizations-Enhanced research	528	Organizations-Enhanced research	160
Documents	541	Documents	511
Total citations	10,998.53	Total citations	13,613.04
Average years from publication	5.94	Average years from publication	5.97
Average citations per documents	20.33	Average citations per documents	26.64
Average citations per year per doc	2.685	Average citations per year per doc	3.52
References	6283	References	13503
Document types		Document types	
Article	232	Article	290
Article; proceedings paper	13	Conference paper	20
Biographical-item	1	Erratum	14
Correction	11	Note	75
Editorial material	63	Editorial	10
Letter	21	Letter	19
Meeting abstract	55		
News item	111	Short survey	14
Review	31	Review	61
Review; book chapter	3	Book chapter	8
Document contents		Document contents	
Keywords Plus (ID)	644	Keywords Plus (ID)	2757
Author's Keywords (DE)	541	Author's Keywords (DE)	614
Authors		Authors	
Authors	2163	Authors	2135
Author Appearances	3889	Author Appearances	3726
Authors of single-authored documents	90	Authors of single-authored documents	85
Authors of multi-authored documents	2073	Authors of multi-authored documents	2050
Authors collaboration		Authors collaboration	
Single-authored documents	169	Single-authored documents	138
Documents per Author	0.25	Documents per Author	0.239
Authors per Document	4	Authors per Document	4.18
Coauthors per Documents	7.19	Coauthors per Documents	7.29
Collaboration Index	5.57	Collaboration Index	5.5

Top 10 most active authors

The top 10 authors with Author Information and Institutions, h_index, Total citation, and the number of publications are presented in Table 3. Feldmann H from the National Institute of Allergy and Infectious Diseases (NIAID), Laboratory Virology, Division of Intramural Research (NIH), Hamilton, USA, was a top ranking author with 35 articles and total citations of 2283 in Wos and 2749 Scopus. This author has 23 articles in the Wos and 26 in Scopus databases. Among the top 10 authors, only Samai M., an African author from the University of Sierra Leone, Faculty of Pharmaceut SCII, College of Medical & Allied Health Science, Sierra Leone, with 13 documents and total citations 134 times in the Wos.

Most productive corresponding author's countries

The 541 articles on Ebola vaccine research published in the WoS database were contributed by 50 corresponding author's countries or regions and 55 countries in Scopus. Findings of the number of publications, single country publications, and multiple-country publications are presented in Table 4. In the top corresponding author country category, the leading role was maintained by authors from the United States in both Wos and Scopus databases, with 382 publications representing 65.05% Wos EBOV vaccine-related publication and 68.18% in Scopus. The United Kingdom authors had 29 publications in the Wos and ranked second while ranking third in the Scopus database with 26 publications. The representation of Nigeria in both Wos and Scopus with a combination of nine publications is of significance given the nonoccurrence of any other African country as corresponding authors. Other corresponding author's countries notable in the top 13 categories are China, India, and Bangladesh. The map of Interstate relations of the EBOV vaccine between the countries' cooperation indexed in the Wos is presented inFigure 2. The global distribution of Ebola vaccine research per year and countries of origins contributed to EBOV vaccine-related research in the Wos is depicted in Figure 3.

Distribution of most productive and active Journals

The top 10 journals according to the number of publications, h_index, Total Citations (TC), Impact factors (IF) and 5 years impact factors (5 years IF) are presented in Table 5. The total number of published articles in the top 20 academic journals were examined to account for their contribution to publishing EBOV vaccine research Journal of Infectious Diseases was the most productive journal (45, 8.32%), followed by Lancet (38, 7.02%), vaccine (36,6.65%), and Human Vaccines & Immunotherapeutics (30,5.54%) were the top-publishing journals indexed in the Wos. The Journal of Infectious Diseases was the most productive (47, 9.2%), followed by Vaccine (36, 7.05%) in the Scopus database.

In the top 10 most productive journals, the Lancet had the highest impact factor (59.345) and the highest number of citations (1319) in the Wos and (1454) in Scopus. The Journal of Infectious Diseases with the highest h-index and the top most productive journal has a total citation of 961 in Wos and 1241 in Scopus. Human Vaccines & Immunotherapeutics have an h_index of 8 and 276 citations, making it the fourth top productive journal in EBOV vaccine-related publications. All publishing journals in the top 10 categories in the Wos and Scopus are publishers from the United States and England, except for "Nature" from Germany.

Subject categories & organizations-enhanced Ebola vaccine research

We classified the 541 (Wos) and 511 (Scopus) documents published in EBOV vaccine research articles into 528 (Wos), and Scopus (160) organizations enhanced the research and Twenty-three (Wos) and 25 (Scopus) subject categories in Table 6. Immunology was the subject category with the most significant number of published articles (172,31.79%) in Wos, followed by Internal General Medicine (99,18.29%) and infectious diseases (98,18.11%) among the reported subjects. National Institute of Health (NIH), USA was the top-rank organization (82,15.15%), followed by NIH National Institute of Allergy Infectious Diseases (NIAID) with (75,13.86%).

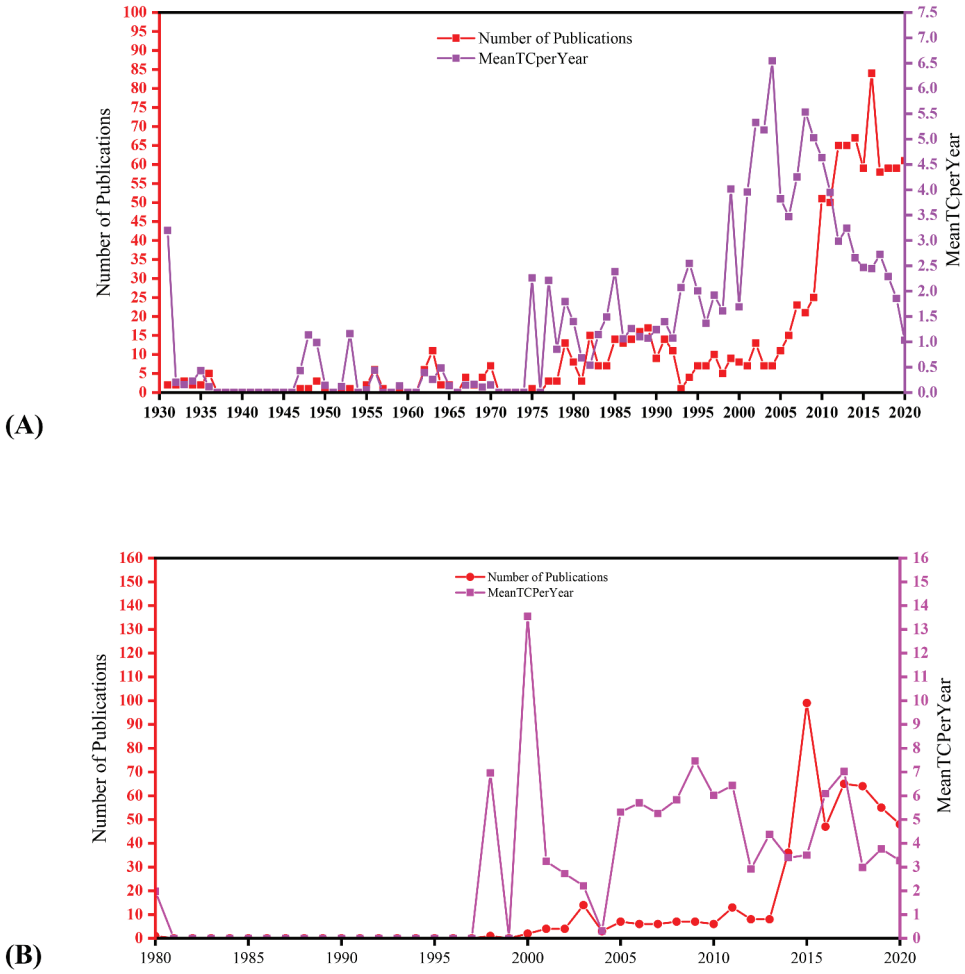


Figure 1. The global trend of the publication and average citations on Ebola vaccine research in WOS (A) Scopus database (B).

Medicine is top of the list with 327 (63.99%) publications in the Scopus database.

Keywords plus analysis

The occurrence of the analysis of the keywords shown the terms infection (71), hemorrhagic-fever (64), nonhuman-primates (60), double-blind (51), immunogenicity (46), protects nonhuman-primates (41), safety (40), disease (36), and immunization (35) (Figure 4(a)). The top 10 keywords in Scopus in Figure 4(b): Ebola vaccine (616), followed by hemorrhagic fever ebola (486), ebolavirus (456), ebola hemorrhagic fever (423), human (366), ebola vaccines (338), vaccination (329), humans (314), priority journal (273), and (272)

The conceptual structure of keywords analysis

The analysis of the 100 keywords plus is distributed into 5 clusters as Cluster 1(DNA. Vaccines), cluster 2 (safety, ring. vaccination, epidemic, efficacy, challenges, Guinea, Liberia, design, and trial). Cluster 3 (t-cell responses, vectored.vaccine, lethal, Ebola, i.clinical. trial, equine encephalitis virus, neutralized antibodies, mouse model, Marburg virus, protects.nonhuman.primates), and cluster 4 include (cell, vaccination, expression vectors among others) as shown in Figure 5(a). Figure 5(b) shows the extension of the conceptual structure of the top 100 keywords in the Scopus database.

Network visualization map

Coauthor analysis refers to establishing the relationship between items according to the number of authors based on total link strength (TLS) to establish a similar relationship between documents. The network visualization of the WoS publication is presented 6A, 6B, and 6C. Close cooperation between authors with the highest number of publications was also presented based on their links. A minimum of three documents of the author were selected, which resulted in 207 meeting the thresholds. The authors Feldmann, Heinz (TLS = 107), Patel, Ami (TLS = 75), Douoguih, Macaya (TLS = 64), among others (Figure 6(a)). A minimum of 5 documents of an organization. A total of 50 organizations meet the thresholds and are presented in the 6 clusters with (TLS = 277). Public health agency Canada (TLS = 77), World Health Organization WHO (TLS = 42), University of Penn (TLS = 31), University of Oxford (TLS = 16), among others (Figure 6(b)). Papers identified in the 50 countries were analyzed using VOSviewer. A minimum of five documents of countries were selected, and it results in 26 (TLS = 615). The USA was reported with (TLS = 229), England (TLS = 123),

Table 2. Top 10 most cited documents on the EBOV vaccine.

Author's, Year, Journal (WoS)	Title	TC	ATC per Year
Sullivan NJ,[19] Nature	Development of a preventive vaccine for Ebola virus infection in primates	509	23.13
Henao-Restrepo AM,[20] The Lancet	Efficacy and effectiveness of an rVSV-vectored vaccine expressing Ebola surface glycoprotein: interim results from the Guinea ring vaccination cluster-randomized trial (Ebola Ça Suffit!)	478	68.28
Jones SM,[21] Nat Med	Live attenuated recombinant vaccine protects nonhuman primates against Ebola and Marburg viruses	427	25.12
Henao-Restrepo AM,[20] Lancet	Preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomized trial (Ebola Ça Suffit!)	374	74.80
Agnandji ST, 2016, New Engl J Med	Phase 1 Trials of rVSV Ebola Vaccine in Africa and Europe	244	40.66
Feldmann H,[22] Nat Rev Immunol	Ebola virus: from discovery to vaccine	195	10.26
Regules JA, 2017, New Engl J Med	A Recombinant Vesicular Stomatitis Virus Ebola Vaccine	182	36.40
Warfield KL, 2007, J Infect Dis	Ebola Virus-Like Particle-Based Vaccine Protects Nonhuman Primates against Lethal Ebola Virus Challenge	182	12.13
Huttner A, 2015, Lancet Infect Dis	The effect of dose on the safety and immunogenicity of the VSV Ebola candidate vaccine: a randomized, double-blind, placebo-controlled phase 1/2 trial	172	24.57
Martin JE, 2006, CLIN Vaccine Immunol	A DNA vaccine for the Ebola virus is safe and immunogenic in a phase I clinical trial	166	10.37
Author's, Year, Journal (Scopus)			
Sullivan NJ,[19] Nature	Development of a preventive vaccine for Ebola virus infection in primates	563	25.59
Henao-Restrepo AM,[20] Lancet	Efficacy and effectiveness of an rVSV-vectored vaccine expressing Ebola surface glycoprotein: interim results from the Guinea ring vaccination cluster-randomized trial (Ebola Ça Suffit!)	522	74.57
Jones SM,[21] Nat Med	Live attenuated recombinant vaccine protects nonhuman primates against Ebola and Marburg viruses	480	28.23
Henao-Restrepo A.M, 2007,The Lancet	Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomized trial (Ebola Ça Suffit!)	455	90.80
Agnandji ST, 2016, New Engl J Med	Phase 1 Trials of rVSV Ebola Vaccine in Africa and Europe	264	44.00
Stanley D.A, 2014, Nature Medicine	Chimpanzee adenovirus vaccine generates acute and durable protective immunity against ebolavirus challenge	243	30.37
Feldmann H,[22] Nat Rev Immunol	Ebola virus: from discovery to vaccine	219	11.52
Regules JA, 2017, New Engl J Med	A Recombinant Vesicular Stomatitis Virus Ebola Vaccine	218	43.60
Warfield, K.L.,2007, Journal of Infectious Diseases	Ebola virus-like particle-based vaccine protects nonhuman primates against lethal Ebola virus challenge	212	14.13
Ewer K., 2016, New England Journal of Medicine	A monovalent chimpanzee adenovirus Ebola vaccine boosted with MVA	211	35.17

TC: Total Citations; ATC per Year: Average of Total Citations Per Year

Table 3. The 10 top most prolific authors on the Ebola vaccine.

Author	Author Information and Institution (WoS)	h_index	TC	NP
Feldmann H	National Institute of Allergy and Infectious Diseases, Laboratory Virology, Division of Intramural Research, Hamilton, USA	23	2283	35
Kobinger GP	University of Manitoba, Winnipeg, Canada	10	458	24
Marzi A	National Institute of Allergy and Infectious Diseases, Rocky Mountain Laboratories, Hamilton, United States	13	591	22
Geisbert TW	University Texas Med Branch, Galveston National Lab, Galveston, USA	13	1577	17
Sullivan NJ	National Institute of Allergy and Infectious Diseases, Bethesda, United States	13	2231	17
Kieny MP	Institute Pasteur, Paris, France & Organization Mondiale de la Santé, Geneva, Switzerland	11	1677	15
Douoguih M	Janssen Vaccines & Prevent, Leiden, Netherlands	6	264	14
Qiu X	National Microbiology Laboratory, Winnipeg, Canada	8	308	14
Samai M	The University of Sierra Leone, Faculty of Pharmaceutical SCII, College of MED & Allied Health Science, Sierra Leone	6	134	13
Feldmann F	NIAID Rocky Mountain Laboratories, Hamilton, United States	9	613	12
Author	**Author Information and Institution (Scopus)**			
Feldmann H	National Institute of Allergy and Infectious Diseases, Laboratory Virology, Division of Intramural Research, Hamilton, USA	26	2749	33
Marzi A	National Institute of Allergy and Infectious Diseases, Rocky Mountain Laboratories, Hamilton, United States	15	811	23
Geisbert TW	University Texas Med Branch, Galveston National Lab, Galveston, USA	18	2080	22
Sullivan NJ	National Institute of Allergy and Infectious Diseases, Bethesda, United States	17	3107	21
Kobinger GP	University of Manitoba, Winnipeg, Canada	13	579	18
Jahrling PB	National Institutes of Health (NIH), Bethesda, United States	12	1342	13
Nabel GJ	National Institute of Allergy and Infectious Diseases, Bethesda, United States	11	1810	13
Qiu X	National Microbiology Laboratory, Winnipeg, Canada	9	373	12
Becker S	Philipps-Universität Marburg, Marburg, Germany	6	790	11
Bavari S	US Army Medical Research Institute of Infectious Diseases, Frederick, United States	8	427	11

H-index: Hirsch index; TC: Total Citation; NP; Number of Publication

Table 4. Top 13 productive corresponding author's countries, scientific impact, and international collaboration on Ebola vaccine research.

Country (n = 50), WoS	NP	TC	AAC	SCP	% SCP	MCP	% MCP	MCP_Ratio
The United States of America	206	6234	30.26	134	65.05	72	34.95	0.350
United Kingdom	29	665	22.93	15	7.28	14	6.80	0.483
Canada	27	1154	42.74	12	5.83	15	7.28	0.556
China	16	352	22.00	12	5.83	4	1.94	0.250
Switzerland	16	1368	85.50	5.0	2.43	11	5.34	0.688
France	10	68	6.80	4.0	1.94	6	2.91	0.600
Germany	10	339	33.90	4.0	1.94	6	2.91	0.600
India	6	42	7.00	4.0	1.94	2	0.97	0.333
Netherlands	6	61	10.17	0.0	0.00	6	2.91	1.000
Italy	5	35	7.00	3.0	1.46	2	0.97	0.400
Russia	5	-	-	4	1.94	1	0.49	0.2
Australia	4	15	5	1	0.49	3	1.46	0.75
Nigeria	4	-	-	3	1.46	1	0.49	0.25
Country (n = 55), Scopus								
The United States of America	176	7364	41.84	120	68.18	56	31.81	0.318
Canada	28	1357	48.46	11	39.28	17	60.71	0.607
United Kingdom	26	677	26.04	13	50.00	13	50.00	0.5
Switzerland	12	1351	112.58	4	33.33	8	66.67	0.667
China	11	196	17.82	9	81.81	2	18.18	0.182
France	9	78	8.67	3	33.33	6	66.67	0.667
India	8	61	7.62	7	87.50	1	12.5	0.125
Germany	7	348	49.71	4	57.14	3	42.85	0.429
Italy	7	42	6.00	5	71.42	2	28.57	0.286
Netherlands	5	93	18.60	0	0.00	5	100	1.00
Nigeria	5	79	15.80	4	80.00	1	20.00	0.20
Bangladesh	4	103	25.75	3	75.00	1	25.00	0.25
Georgia	4	43	10.75	4	100.00	0	0.00	0.000

NP: Number of Publications; TC: Total Citations; AAC: Average Article Citations; SCP: Single Country Publications; MCP: Multiple Country Publications

France (TLS = 81), Australia (TLS = 11), Canada (TLS = 59), Sierra Leone (TLS = 36), South Africa (TLS = 28), Gabon (TLS = 22), Nigeria (TLS = 14), and Spain (TLS = 9) among others (Figure 6(c)).

The close cooperation between authors with the highest number of publications was also presented based on their links in the Scopus database. A minimum of three documents of the author were selected, which resulted in 218 meeting the thresholds. The authors Feldmann, Heinz (TLS = 129), Koup RA (TLS = 65), and Russell JBW (TLS = 41), among others (Figure 7(A)).

A minimum of two documents per organization and 148 organizations meets the thresholds and are presented in 11 clusters (TLS = 616). The Center for Vaccine Development (TLS = 46), followed by the Department of Medical Microbiology (TLS = 23), among others (Figure 7(B)).

Papers identified in the 50 countries were analyzed using VOSviewer. A minimum of 5 countries was selected, and it results in 26 meet the thresholds and presented into 5 clusters with (TLS = 592). The USA was reported with (TLS = 227), United Kingdom (TLS = 118), Switzerland (TLS = 96), Netherlands (TLS = 67), France (TLS = 65), Canada (TLS = 56), Sierra Leone (TLS = 21), and Nigeria (TLS = 18), among others (Figure 7(C)).

Discussion

The 20th century saw an explosion in research output across all medical and scientific fields.[23] EBOV, being highly pathogenic for humans and nonhuman primates and the subject of former weapons programs is now one of the most feared pathogens worldwide.[22] The development of the EBOV vaccine is crucial to the eradication of the virus. There is, however, remarkable clinical progress in the development of an approved vaccine. The present study provides a comprehensive overview of the global research productivity of the Ebola vaccine indexed in the WoS and Scopus databases. The results indicated that the research trend on the EBOV vaccine has increased over the years.

The top most cited document on the Ebola vaccine was published in Nature by Sullivan NJ (2000) under the title Development of a Preventive Vaccine for EBOV Infections in primates. Meanwhile, the second paper titled "Efficacy and effectiveness of an RVSV-vectored vaccine expressing Ebola surface glycoprotein: interim results from the Guinea ring vaccination cluster-randomized trial," was published by Henao-Restrepo AM (2015) in The Lancet. These two articles were the top two most cited in the two databases explored in the study.

The Journal of Infectious Diseases, Lancet, Vaccine, Human Vaccines, Immunotherapeutics and Lancet Infectious Diseases were the most productive published journals in the EBOV vaccine-related research. Both the Lancet and Journal of Infectious Diseases had the highest impact factor and the highest number of citations. The United States of America (USA), the United Kingdom, and Canada had the highest number of documents, total citations, and average citations. The USA is the leading country because the top-ranking organizations that fund EBOV vaccine research are dominated by the National

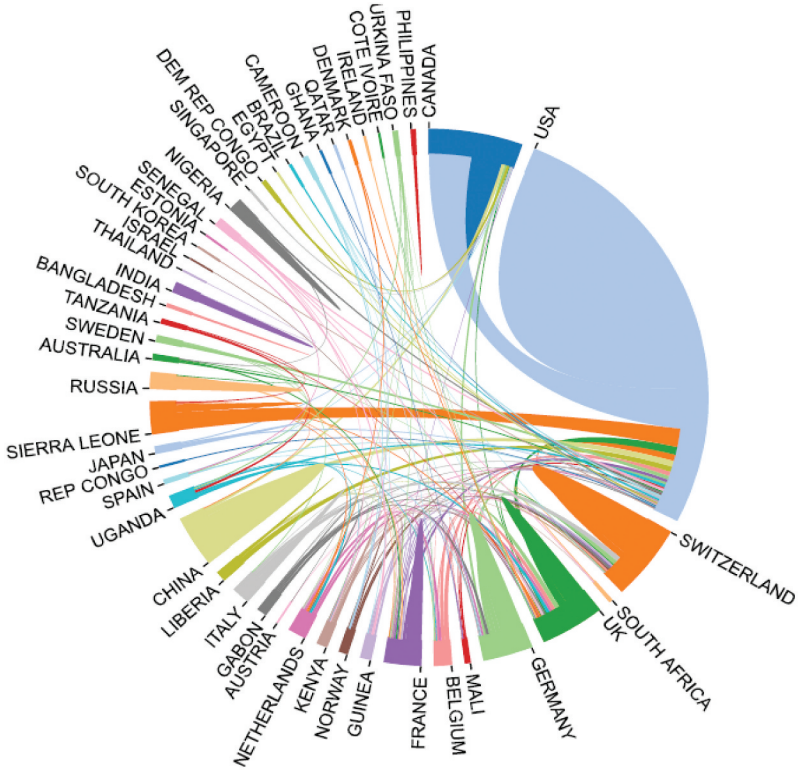


Figure 2. Inter-state relations of Ebola vaccine between the countries in indexed WoS.

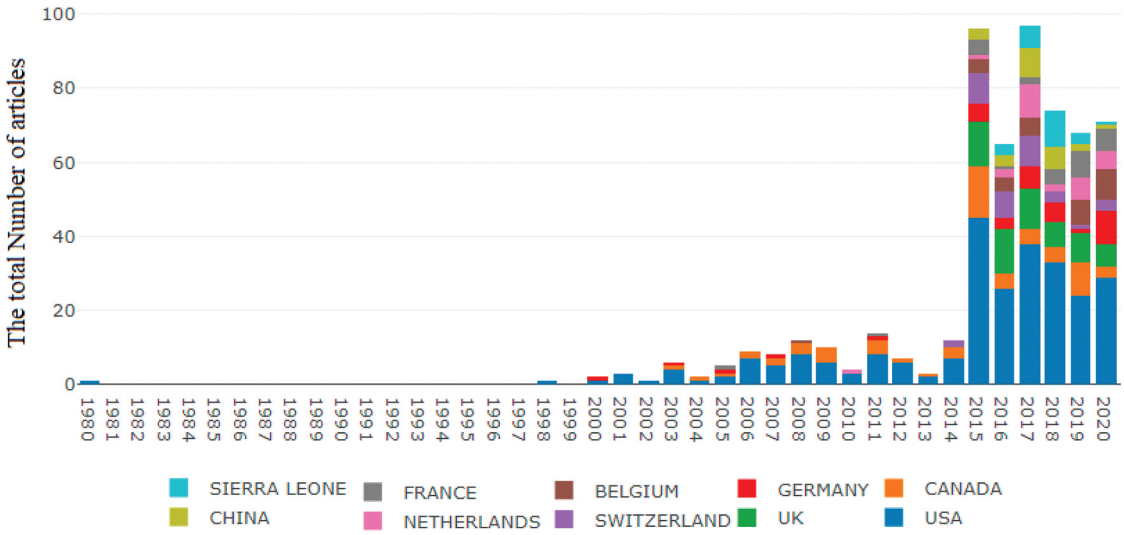


Figure 3. Global distribution of Ebola vaccine research in the world per year indexed in WoS.

Institutes of Health (NIH) and the National Institute of Allergy Infectious Diseases (NIAID) from the USA.

The highest-ranking researchers,' analysis showed that Feldmann H from the USA was the top ranking author in WoS and Scopus publications explored. Some of his early papers highlight reviews about virus vaccine discovery,[24] and Lessons on Vaccine Development.[25] At the same time, the recent review paper was about virus, epidemiology, disease, and pathogenesis, diagnosis, patient care, treatment, vaccine, outbreak management, perspective on the future.[26] Simultaneously, Samai M was the only African author among the top 10 who contributed to EBOV vaccine research. In his study concerning the Sierra Leone Trial to Introduce a Vaccine Against EBOV, he studied the recombinant vesicular stomatitis virus Ebola vaccine (rVSVΔG-ZEBOV-GP) safety and efficacy.[27]

In the present study, the published articles are indexed in many research categories in the WoS, including immunology, general internal medicine, and infectious diseases, and the Scopus had "Medicine," Immunology, and

Table 5. Top 10 most productive and active journals published research on the Ebola vaccine.

Source (n = 141)	H_index	TC	NP	(%)	IF (2019)	5 year IF	Publisher
Journal of Infectious Diseases	17	961	45	8.32	5.022	5.057	USA
Lancet	10	1319	38	7.02	60.39	59.345	USA
Vaccine	13	829	36	6.65	3.143	3.192	England
Human Vaccines &Immunotherapeutic	8	276	30	5.54	2.619	2.716	USA
The Lancet Infectious Diseases	10	594	23	4.25	24.446	22.945	England
Science	6	133	23	4.25	41.846	44.374	USA
American Journal of Tropical Medicine and Hygiene	3	18	22	4.07	2.126	2.439	USA
BMJ-British Medical Journal	4	102	19	3.51	30.313	28.025	England
JAMA-Journal of the American Medical Association	6	273	16	2.96	45.54	47.677	USA
Journal of Virology	10	679	13	2.40	4.501	4.288	USA
Source (n = 185)							
Journal of Infectious Diseases	20	1241	47	9.20	5.022	5.057	USA
Vaccine	13	947	36	7.05	3.143	3.192	England
The Lancet	9	1454	31	6.07	60.39	59.345	USA
The Lancet Infectious Diseases	9	642	21	4.11	24.446	22.945	England
Human Vaccines and Immunotherapeutics	9	303	18	3.52	2.619	2.716	USA
Journal of Virology	13	1061	18	3.52	4.501	4.288	USA
BMJ-British Medical Journal	3	64	14	2.74	30.313	28.025	England
SCIENCE	6	138	13	2.54	41.846	44.374	USA
Expert Review of Vaccines	7	263	12	2.35	4.362	3.893	England
Nature	5	674	11	2.15	42.779	46.488	Germany

H-index: Hirsch index; TC: Total Citations; NP: Number of Publications; IF: Impact Factors

Microbiology top two categories. However, the terms' infection, hemorrhagic-fever, nonhuman-primates, double-blind, immunogenicity, protection of non-human-primates, safety, disease, and immunization were the most common keywords in the Wos. On the other hand, in Scopus, the terms such as ebola vaccine, hemorrhagic fever ebola, and vaccination were some of the most occurring keywords. These reported keywords indicate the significant areas of interest in the EBOV vaccine and future research directions.

The bibliometric analysis highlights the global effort to speed up progress on the EBOV vaccine, which will benefit the population currently at risk of contracting the virus. Although only one EBOV vaccine has been approved in the United States, there are still several species variations and the futuristic potentiality of mutation. Thus, research efforts must continue to ensure that an effective vaccine is developed. Also, the population most vulnerable to EBOV infection is in sub-Sahara Africa, and there is significant infection reported from the region from time to time based on the ecological uncertainty of the virus.[28] An exposition from the current study analysis shows limited research contribution, authorship, collaboration, and funding for the EBOV vaccine from Africa. This evidence highlights a significant disadvantage from the region based on the premise that the areas most impacted by the virus outbreak.[29] The lack of proactiveness from clinical researchers from Africa, collaboration, and lack of available research funds may hamper efforts to abate the rate of infection and vaccine progress. Therefore, policy interventions for research and vaccine development should be encouraged in the region most affected by EBOV.

Table 6. Top 10 categories of Wos & organizations-enhanced Ebola vaccine research.

Web of Science Categories (n = 23)	NP	(%)	Organizations-Enhanced (528)	NP	(%)
Immunology	172	31.79	National Institutes of health, USA	82	15.15
Internal General Medicine	99	18.29	National Institutes of Health & National Institute of Allergy Infectious Diseases	75	13.86
Infectious Diseases	98	18.11	University of Texas System	38	7.024
Medicine research Experimental	86	15.89	University of Manitoba	36	6.654
Microbiology	72	13.30	Public Health Agency of Canada	35	6.470
Biotechnology Applied Microbiology	55	10.16	Centers for Disease Control Prevention, USA	28	5.176
Multidisciplinary Sciences	47	8.68	University of london	27	4.991
Public Environmental Occupational Health	47	8.68	University of Texas Medical Branch Galveston	24	4.436
Virology	40	7.39	London school of hygiene tropical medicine	23	4.251
Tropical medicine	29	5.36	University of Oxford	22	4.06
Biochemistry Molecular Biology	18	3.32	World Health Organization (WHO)	22	4.06
Scopus categories (n = 25)			**Organizations-Enhanced (160)**		
Medicine	327	63.99	National Institute of Allergy and Infectious Diseases	110	21.53
Immunology and Microbiology	170	33.27	National Institutes of Health,	87	17.03
Biochemistry, Genetics and Molecular Biology	116	22.70	U.S. Department of Health and Human Services	53	10.37
Pharmacology, Toxicology and Pharmaceutics	90	17.61	Horizon 2020 Framework Programme	23	4.50
Multidisciplinary	41	8.02	Wellcome Trust	23	4.50
Veterinary	37	7.24	Canadian Institutes of Health Research	20	3.91
Agricultural and Biological Sciences	30	5.87	Biomedical Advanced Research and Development Authority	17	3.33
Engineering	11	2.15	European Commission	17	3.33
Social Sciences	10	1.96	Defense Threat Reduction Agency	15	2.94
Chemical Engineering	8	1.57	Public Health Agency of Canada	15	2.94

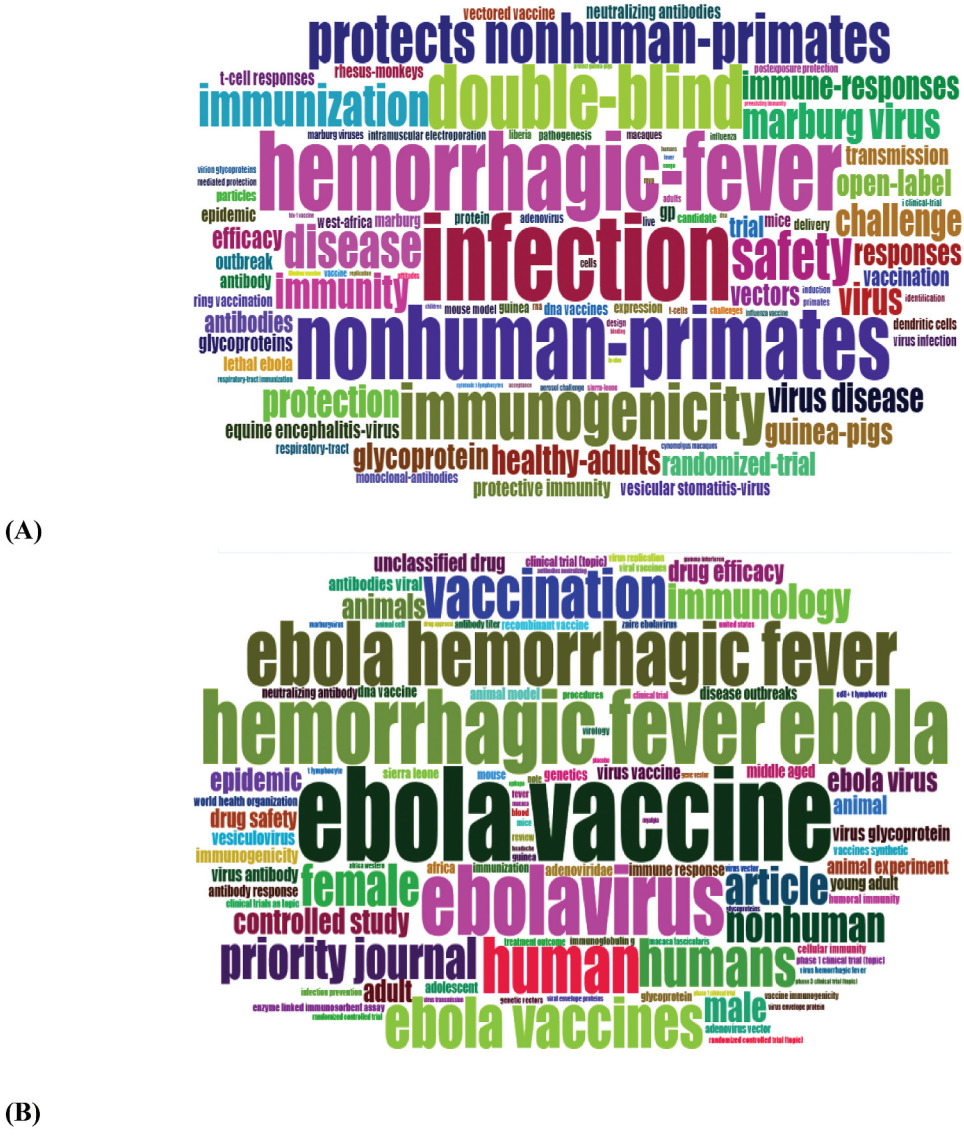


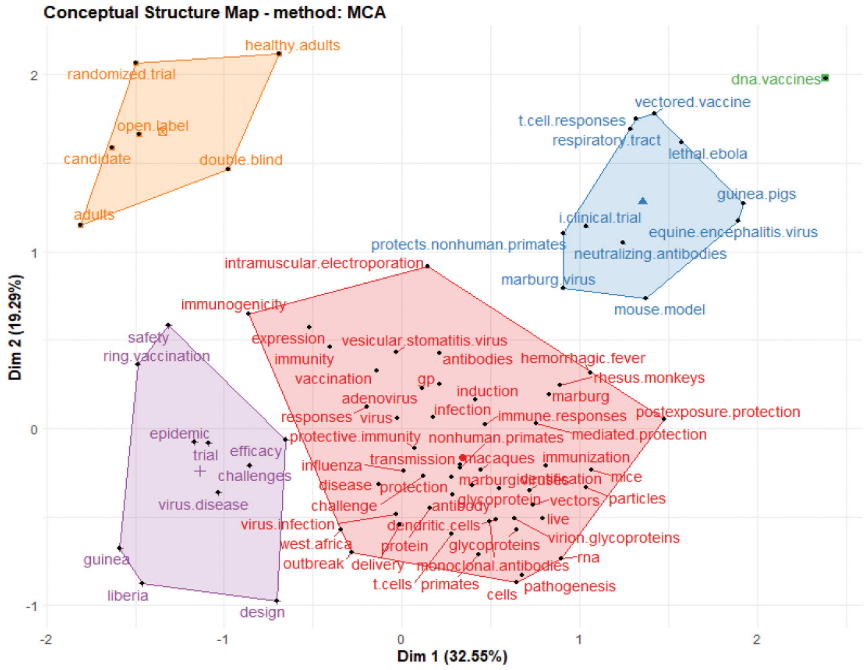
Figure 4. Occurrence of Keyword Plus using WordCloud Visualization analysis in WoS (4A) and Scopus (4B).

Strength and limitation

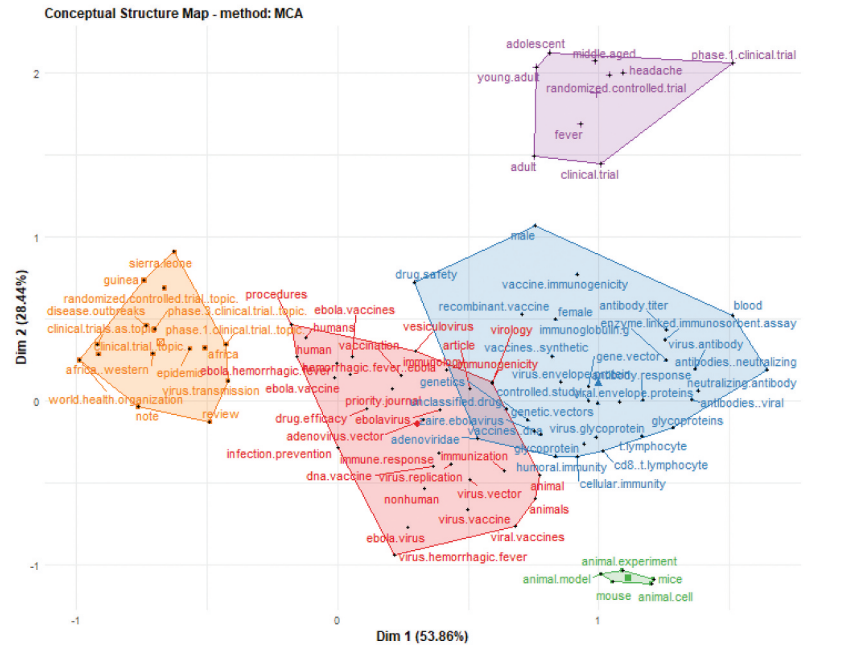
The current EBOV vaccine research analysis gives a comprehensive mapping and 'snapshot' of the research trends and production for documents indexed in the WoS and Scopus databases. Although it provides the reader with complete information on the research productivity and insight into EBOV vaccine research characteristics, there are few limitations to be considered. For example, the presence of false positive and false-negative results must be regarded as in any bibliometric study. Also, only two databases (Web of Science and Scopus) were used for analysis and focused only on English published documents. Other databases, such as PubMed, Google Scholar, and some foreign databases were not included in the investigation to present an all-inclusive bibliometric analysis. We also assessed the top-cited articles based on the total citation score. However, authors have self-citations that can have an impact on the overall number of citations and h-index. Besides these limitations, the study also shows that the EBOV vaccine citation increased in 2015 and provides essential insights on countries with the highest contribution to the EBOV vaccine research and African researcher's contribution to scientific research production. The study also proposes the importance of building and sustaining research collaborations between African countries in developing the Ebola vaccine.

Conclusions

The progress in EBOV vaccine research is acknowledged given the total number of publications in the Wos and Scopus databases. These two databases are comprehensively



(A)



(B)

Figure 5. The conceptual structure of top 100 Keywords using Multiple Correspondence Analysis (MCA) indexed in WOS (5A) and Scopus database (5B).

the most widely accessible repository globally, and the extraction of publications from the two databases gives an apt insight into the global progress of EBOV vaccine research to measure research performance and milestones. Hence, this study is the first attempt to present bibliometric evidence on the international research output of EBOV vaccine research which consolidated the recent global research publication on EBOV.[2] In over 30 years of research on the EBOV vaccine, only one vaccine has been approved to counter the EBOV virus in Zaire Region.[11] Thus, there is a need to intensify vaccine development research efforts to produce more result-oriented evidence by ensuring that more vaccines are developed and approved for immediate remedial action in regions plagued with

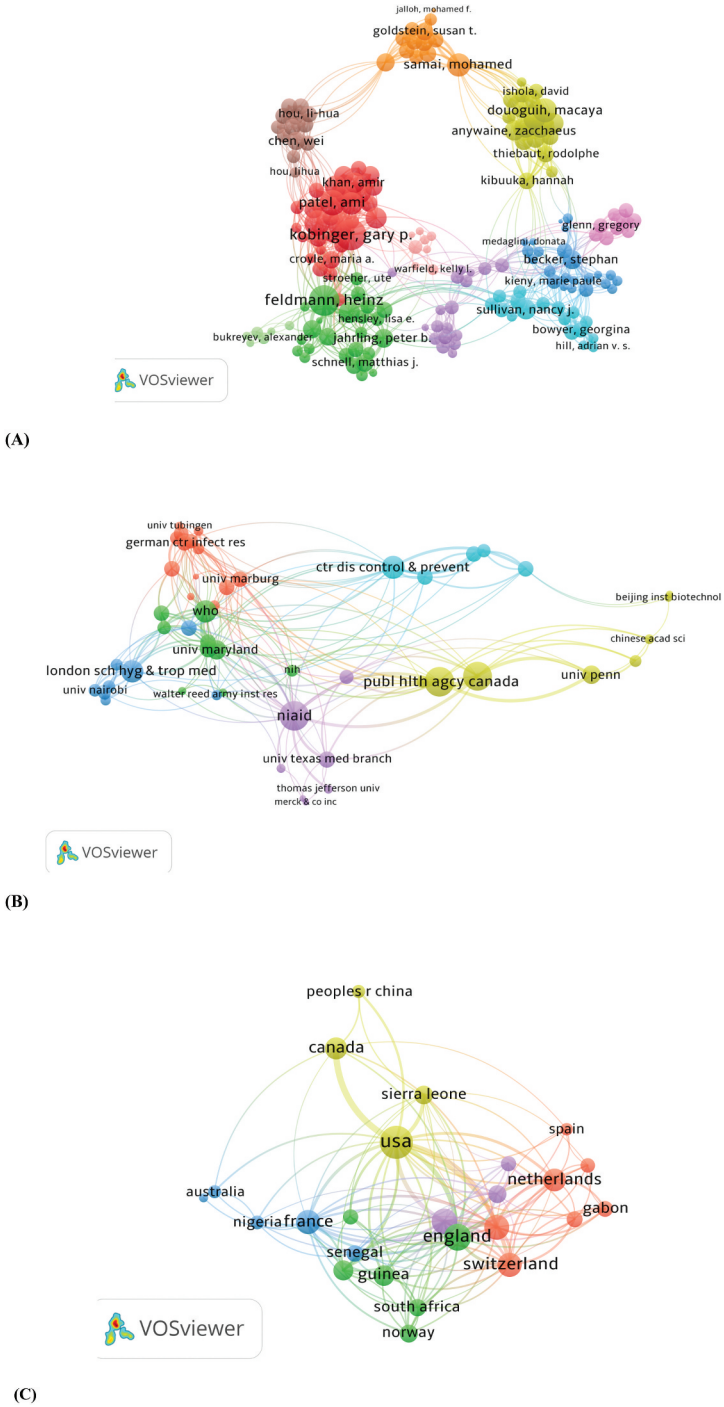


Figure 6. Network visualization map of country coauthorships (**6A**), organizations (6B), and countries (6C) indexed in WoS.

disease outbreaks, such as the ongoing outbreaks in DRC and Guinea.

Furthermore, there is a need for health stakeholders such as the WHO to intensify support through funding and engaging scientists to develop an EBOV vaccine urgently. The focus should be on developing a vaccine that can offer immune support for all EBOV variants from low-resourced African countries. This bibliometric analysis has exposed the shortage of research contributions from scientists from the affected African region, with the exception of Nigeria taking the leading role. Therefore, it becomes imperative to address this shortfall through policy redress and an increase in research funding for the underperforming African countries.

The study concludes that the Ebola vaccine's research trends increased over the years, especially in non-human-primates, immunogenicity, and vaccine safety. In addition, the developed countries contributed more research on the Ebola vaccine

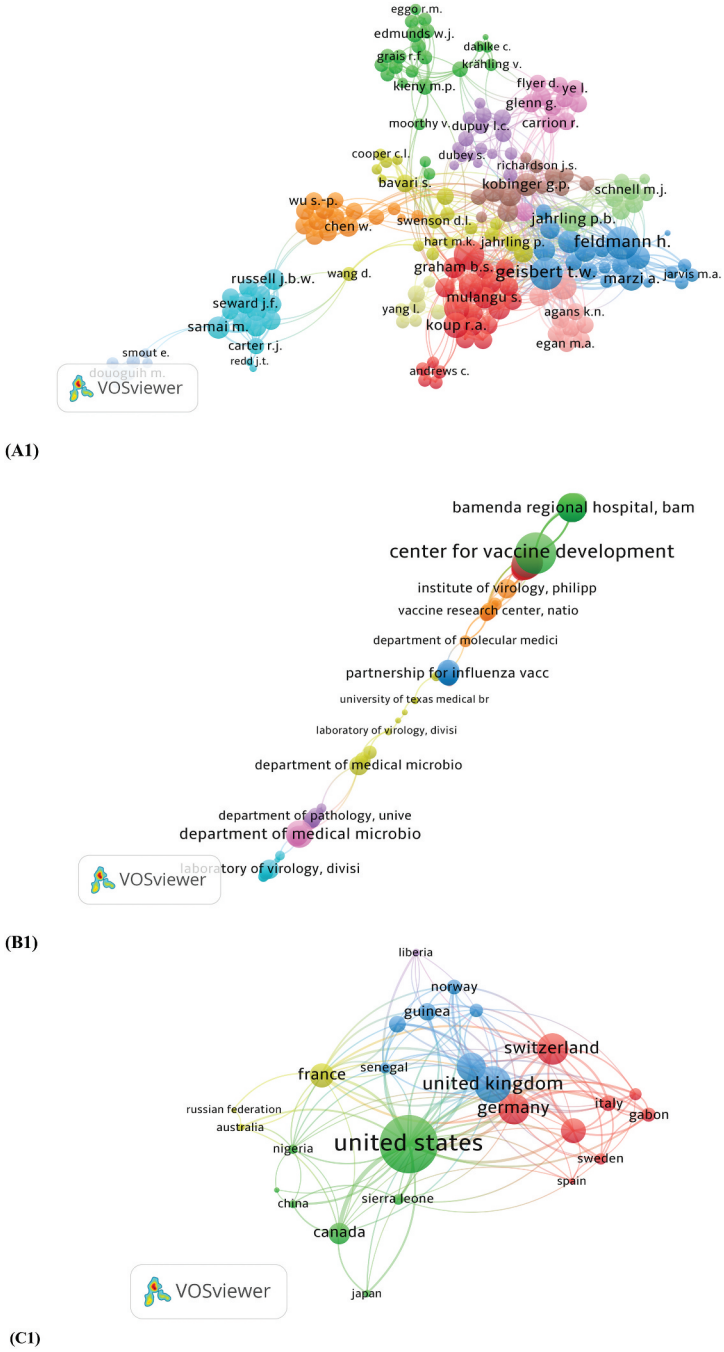


Figure 7. Network visualization map of country coauthorships (6A1), organizations (6B1), and countries (6C1) indexed in Scopus database.

compared with developing countries. Therefore, while groundbreaking EBOV vaccines that will take care of all species existing can be anticipated, global efforts must continue in clinical research, collaborations, and funding availability.

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Data access

All data presented in this article can be retrieved from WoS and Scopus using keywords listed in the methodology.

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No potential conflicts of interest were disclosed.

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Author's contributions

TYA and THM Conceived the idea and designed the study; TYA and THM: Searched and collected the data; TYA, EI, and HHM: Wrote the first draft of the manuscript; TYA and THM: Software and formal analysis; TYA, THM, HHM, EI, JK, SC and SM: Reviewed and edited the final draft. All the authors read and approved the final manuscript for publication.

References

1. Beeching NJ, Fenech M, Houlihan CF. Ebola virus disease. BMJ. [Internet] 2014; 349:1–15. doi:10.1136/bmj.g7348.
2. Kawuki J, Yu X, Musa TH. Bibliometric analysis of ebola research indexed in web of science and Scopus (2010-2020). Biomed Res Int. 2020;2020:1–12. doi:10.1155/2020/5476567.
3. Rewar S, Mirdha D. Transmission of Ebola virus disease: an overview. Ann Glob Heal. [Internet] 2014; 80:444–51. doi:10.1016/j.aogh.2015.02.005.
4. CDC. History of Ebola virus disease (EVD) outbreaks (B) [Internet]. [accessed 2021 Apr 10]. https://www.cdc.gov/vhf/ebola/history/summaries.html?CDC_AA_refVal=https%3A%2F%2Fwww.cdc.gov%2Fvhf%2Febola%2Foutbreaks%2Fhistory%2Fsummaries.html.
5. WHO. WHO | ebola virus disease – guinea. WHO. MSF.org. [Internet] 2021. [accessed 2021 Apr 10]. http://www.who.int/csr/don/17-february-2021-ebola-gin/en/.
6. Kawuki J, Musa TH, Yu X. Impact of recurrent outbreaks of Ebola virus disease in Africa: a meta-analysis of case fatality rates. Public Health [Internet] 2021; 195:89–97. [accessed 2021 Jun 2]. https://linkinghub.elsevier.com/retrieve/pii/S0033350621001396.
7. Ebola virus disease [Internet]. [accessed 2021 May 31]. https://www.who.int/health-topics/ebola#tab=tab_1.
8. Ebola DRC KIVU. Dashboard redone [Internet]; 2018. [accessed 2021 May 31. https://who.maps.arcgis.com/apps/opsdashboard/index.html#/e70c3804f6044652bc37cce7d8fcef6c.
9. OMS. Technical information note: WHO recommended criteria for declaring the end of the Ebola virus disease outbreak. 2020. [accessed 2021 Apr 10]. https://www.who.int/who-documents-detail/who-recommended-criteria-for-declaring-the-end-of-the-ebola-virus-disease-outbreak.
10. Bishop BM. Potential and emerging treatment options for ebola virus disease. Ann Pharmacother. 2015;49:196–206. doi:10.1177/1060028014561227.
11. Ebola vaccine: information about Ervebo® | clinicians | ebola (Ebola virus disease) | CDC [Internet]. [accessed 2021 Apr 10]. https://www.cdc.gov/vhf/ebola/clinicians/vaccine/index.html.
12. Yi F, Yang P, Sheng H. Tracing the scientific outputs in the field of Ebola research based on publications in the web of science. BMC Res Notes. 2016. doi:10.1186/s13104-016-2026-2.
13. Chahrour M, Assi S, Bejjani M, Nasrallah AA, Salhab H, Fares MY, Khachfe HH, Bibliometric A. Analysis of COVID-19 research activity: a call for increased output. Cureus. 2020;12(3):e7357.
14. Musa TH, Akintunde TY, Musa HH, Ghimire U, Gatasi G. Malnutrition research output: a bibliometric analysis for articles index in web of science between 1900 and 2020. Electron J Gen Med. 2021;18(3):em293.
15. Musa TH, Akintunde TY. Global scientific research output on sickle cell disease : a comprehensive bibliometric analysis of web of science publication. Sci African. [Internet] 2021; 12:e00774. doi:10.1016/j.sciaf.2021.e00774.
16. Garfield E, Paris SW, Stock WG. HistCite™: a software tool for informetric analysis of citation linkage. Information-wiss und Prax. 2006;5:1143–1153.
17. Dervis H. Bibliometric analysis using bibliometrix an R package. J Scientometr Res. 2019;8(3):156–160.
18. Van Eck NJ, Waltman L. Software survey: VOSviewer, a computer program for bibliometric mapping. Scientometrics. 2010;84(2):523–38. doi:10.1007/s11192-009-0146-3.
19. Sullivan NJ, Sanchez A, Rollin PE, Yang ZY, Nabel GJ. Development of a preventive vaccine for Ebola virus infection in primates. Nature. 2000;408:605–09. doi:10.1038/35046108.
20. Henao-Restrepo AM, Camacho A, Longini IM, Watson CH, Edmunds WJ, Egger M, Carroll MW, Dean NE, Diatta I, Doumbia M, et al. Efficacy and effectiveness of an rVSV-vectored vaccine in preventing Ebola virus disease: final results from the Guinea ring vaccination, open-label, cluster-randomised trial (Ebola Ça Suffit!). Lancet. [Internet] 2017; 389:505–18. [accessed 2021 May 31].
21. Jones SM, Feldmann H, Ströher U, Geisbert JB, Fernando L, Grolla A, Klenk HD, Sullivan NJ, Volchkov VE, Fritz EA, et al. Live attenuated recombinant vaccine protects nonhuman primates against Ebola and Marburg viruses. Nat Med. 2005;11:786–90. doi:10.1038/nm1258.
22. Feldmann H, Jones S, Klenk H, Schnittler H. Ebola virus: from discovery to vaccine. Nature Reviews. Immunology. 2003;3(8):677–85. doi:10.1038/nri1154.
23. Musa TH, Musa IH, Osman W, Campbell MC, Musa HH. A bibliometric analysis of global scientific research output on Gum Arabic. Bioact Carbohydrates Diet Fibre. 2021;25:100254. doi:10.1016/j.bcdf.2020.100254.
24. Traf U, Sullivan NJ, Sanchez A, Rollin PE, Yang Z, Nabel GJ. Development of a preventive vaccine for Ebola virus infection in primates. Nature. 2000;408(6812):605–609.
25. Feldmann H, Feldmann F, Marzi A. Ebola: lessons on vaccine development. Annu Rev Microbiol. 2018;72:423–46. doi:10.1146/annurev-micro-090817-062414.
26. Feldmann H, Sprecher A, Geisbert TW. Ebola. N Engl J Med. 2020;382:1832–42. doi:10.1056/NEJMra1901594.
27. Schuchat A, Seward JF, Goldstein ST, Mahon BE. Comment: the Sierra Leone trial to introduce a vaccine against Ebola (STRIVE). J Infect Dis 2018;217:S1–5. doi:10.1093/infdis/jix665.
28. Jacob ST, Crozier I, Fischer WA, Hewlett A, Kraft CS, De la Vega MA, Soka MJ, Wahl V, Griffiths A, Bollinger L, et al. Ebola virus disease [Internet]. Nature Rev Dis Primers. 2020;6:13. doi:10.1038/s41572-020-0147-3.
29. Coltart CEM, Lindsey B, Ghinai I, Johnson AM, Heymann DL. The Ebola outbreak, 2013–2016: old lessons for new epidemics. Philos Trans R Soc B Biol Sci. 2017;372(1721):2013–16. doi:10.1098/rstb.2016.0297.