

# The 100 top-Cited Studies on Ebola: A Bibliometric Analysis

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## Research Article

**Keywords:** Ebola, Bibliometric analysis, 100 top-cited, Citation classics, Web of Science

**Posted Date:** August 6th, 2020

**DOI:** <https://doi.org/10.21203/rs.3.rs-53549/v1>

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**Version of Record:** A version of this preprint was published at Electronic Journal of General Medicine on February 13th, 2021. See the published version at <https://doi.org/10.29333/ejgm/9694>.

# Abstract

**Background:** The achievements in Ebola virus disease (EVD) prevention and control can be reflected by scientific studies, particularly in the top-cited studies. The study thus aimed to identify and characterise the 100 top-cited studies of Ebola.

**Methods:** The study used a retrospective bibliometric analysis, which was performed in January 2020. Studies were searched from the Web of Science using the keywords: “Ebola” or “Ebola virus” or “Ebola virus disease” to identify the 100 top-cited ebola studies. Studies were analysed for the number of citations, authorship, and journal, year of publication, country and institution. The analyses were carried out using SPSS, HistCite and VOSviewer.

**Results:** The 100 top-cited studies were published between 1977 and 2017, were cited from 169 to 808 times and had an average citation of 290.5, and 8 studies were cited more than 500 times. They were published in 31 journals, and Journal of Virology published most of the studies (n=14). They were produced by 33 countries, and the USA published most of the studies (63), followed by Germany (8) and Gabon (6). Centre for Disease prevention and Control-USA (26) was the leading institution, while Geisbert TW and Sanchez A were the most productive authors.

**Conclusions:** This study provides insights into the historical advancements reflected by the top-cited studies and has highlighted the leading roles played by various stakeholders in addressing EVD. However, the contribution of African countries is not sufficiently reflected among these studies, and so more focus, funding and involvement in clinical research is needed for effective prevention and control of EVD in Africa.

## Introduction

Ebola virus disease (EVD) is a severe, often fatal zoonosis that is highly infectious in humans [1]. It is caused by negative-stranded RNA viruses, belonging to the Filoviridae family, which are endemic to regions of the west and equatorial Africa [2]. The first EVD human case was identified in 1976 in Zaire, the now called the Democratic Republic of Congo (DRC) [3]. Since then, there have been over 30 documented outbreaks with the worst, and most publicised being the 2014 West African outbreak and the recent 2018–2020 Kivu outbreak in DRC [3, 4].

The origin of the Ebola Virus is not known, but in most outbreaks, it is suspected to be introduced into the human population via forest bats and other wild animals [5]. EVD is known to present with flu-like symptoms, persistent fever, and severe complications such as respiratory disorders, symptoms of hemorrhagic diathesis, among others [6]. In the previous EVD outbreaks, the case fatality of around 25–90% has been reported [1, 2]. The severity of the epidemic has been attributed with the species involved, and the Zaire ebolavirus species is the most lethal strain of the six known Ebola virus sub-strains [3].

Despite the recurrent outbreaks and other challenges, several studies on Ebola have been conducted over time, with remarkable progress in vaccine development [7], as well as prevention and control of EVD [8, 9]. The achievements in EVD prevention and control can be reflected by scientific studies, particularly in the top-cited studies [10, 11]. Citation analysis, a type of bibliometric analysis involves the evaluation and ranking of an article based on citation count [12]. Identification of milestones in a particular field can be done by analysing the most cited studies, especially the 100 top-cited studies [13–15]. Evaluation of the 100 top-cited studies had been conducted for various medical fields and diseases, including tuberculosis [15], diabetes [14], Vaccines [16], Arthritis [17], among others. However, there is no such study conducted on Ebola. Thus, we performed this study to identify and characterise the 100 top-cited studies of Ebola.

## Methods

The study was a retrospective bibliometric analysis, and no ethical approval was required since the data used was from a public database, and no human or animal subject was directly involved.

## Search Method And Strategy

We performed a search on 13th January 2020 using the Web of Science Core Collection database hosted by Clarivate Analytics as the previous studies [14, 17]. The Web of Knowledge Core Collection is a multidisciplinary database with searchable author abstracts and fully indexes the major journals, more than 170 subject categories, and thus provides access to current information and retrospective data from 1900 forward. The following keywords were used for searching the relevant studies: “Ebola” or “Ebola virus” or “Ebola virus disease” in the titles or abstracts of the papers. However, based on a pilot search, the authors found that some top-cited articles mentioning the word Ebola in the abstract are not related to the Ebola, and these studies were excluded. The search was also refined to only research articles for a precise evaluation of the top-cited Ebola studies; other document types were excluded from the analysis. The identified publications were sorted in descending order of citation times and then downloaded as full records in plain text format for further analysis.

## Data Extraction

The following data were extracted, including the author, affiliation, country, journal, language, document type, research field, publication year, and the number of citations. The journal impact factor was obtained from Journal Citation Reports (JCR) ©Ranking: 2018 [18].

## Bibliometric And Statistical Analysis

The bibliometric indicators of Ebola studies such as trends of publication, distribution of countries, Journals, authors, and institutions, total citations, average citations per item, and h-index, were evaluated

using HistCite Software [19], and “Bibliometrix app.” – (using R-studio cloud) [20]. Microsoft Excel and VOSviewer (Van Eck & Waltman, Leiden University, The Netherlands) were used for data mining, mapping and visualisation of the bibliometric networks [21].

Statistical analyses were executed using Statistical Package for the Social Sciences for windows software (version 20.0, IBM SPSS-Chicago, IL: SPSS Inc.). Frequency statistics of the 100 top-cited articles were reported. A nonparametric Spearman correlation ( $r$ ) was used to identify the association between the number of citations and various study variables. A P-value of  $< .05$  was considered statistically significant.

## Results

### Citation classics of the 100 top-cited studies

The 100 top-cited articles are listed in **Supplementary Table 1**. The number of citations ranged from 169 to 808, with a total number of citations equal to 29,026 and average citations of 290.5 per document. Eight studies were cited more than 500 times, and no single-authored paper was noted. The most cited study was published by Aylward B et al., 2014 in the New England Journal of Medicine, with 808 citations.

### Production trend of the top-cited studies

All the 100 top-cited studies were published in the English language. They were published during a span of 40 years from 1977 to 2017; most of the studies were done and published in the late 1990s and 2000s. We found that the highest number of studies was published in 1999( $n=13$ ), 2003(9) and 2014(8). The annual total citation followed an almost similar trend, with 2014 receiving the highest citations of over 3600. (Figure 1)

**Figure 1:** Annual trend and citation of EVD publications (1977 to 2017)

### Most productive Journals

The 100 top-cited articles were published in 31 journals, of which 10 journals published more than 1 study. The most productive journals were United States (US) and United Kingdom (UK) journals, which included the Journal of Virology ( $n=14$ ,  $TC=3620$ ), followed by Journal of Infectious Diseases (9) and Lancet (9), among others. Overall, the 10 top journals published over three thirds (77%) of the top-cited ebola studies. The impact factors (IF) of the top journals ranged from 2.66 to 70.67, while their  $h$ -index ranged from 2 to 14. (**Table 1**)

**Table 1: Journals that published three or more of the 100 top-cited studies**

Rank	Journal	Country location	Number of studies	IF (2018)	h-index	Total citations
1	Journal of Virology	United States	14	4.32	14	3620
2	Journal of Infectious Diseases	United States	9	5.04	9	2001
3	Lancet	United Kingdom	9	59.10	9	2857
4	New England Journal of Medicine	United States	9	70.67	9	3094
5	Proceedings of the National Academy of Sciences of USA	United States	9	9.58	9	2605
6	Science	United States	8	41.04	8	2602
7	Nature	United Kingdom	7	43.07	7	3117
8	Nature Medicine	United States	5	30.64	5	1756
9	PLoS Pathogens	United States	4	6.46	4	965
10	Bulletin of the World Health Organization	Switzerland	3	6.82	3	935

### Country contribution and most cited countries

The top cited studies were produced by 33 countries, of which 15 countries were corresponding author countries that, chaired one or more of the 100 top-cited ebola studies. The USA chaired 63 studies, followed by Germany (8) and Gabon (6). Regarding single-country studies (SCS), still, the USA and Germany topped the list with 32 and 4 studies respectively. Only two SCS came from Africa being produced from DRC and South Africa, as shown in **table 2**. The most cited countries included USA (TC=17405), Germany (2522), Gabon (1663), United Kingdom (1409), among others.

**Table 2: Countries that lead one or more of the 100 top-cited studies of EVD**

Rank	Country	Number of studies	Single-country Studies	Multiple Country Studies	Total citations
1	USA	63	32	31	17405
2	Germany	8	4	4	2522
3	Gabon	6	0	6	1663
4	Canada	4	1	3	1006
5	France	3	0	3	621
6	United Kingdom	3	1	2	1409
7	Netherlands	2	2	0	826
8	Switzerland	2	0	2	671
9	Belgium	1	0	1	242
10	Congo	1	1	0	443
11	Japan	1	0	1	227
12	Russia	1	1	0	268
13	Sierra Leone	1	0	1	610
14	South Africa	1	1	0	211
15	Spain	1	1	0	417

### Most contributing Authors

The 100 studies were written by 1028 authors, and 12 authors wrote at least 7 articles. All the 100 studies were done in collaboration amongst different authors, no single-authored study was recorded, and Authors per document was 10.3 with a Collaboration index of 10.3. The most productive authors of these studies included Geisbert TW and Sanchez A, both with 13 papers, followed Rollin PE (12), Jahrling PB (11) and Peters CJ (11), among others. The top productive authors were mainly from the US and Germany institution such as US Army of Medical Research Institute of Infectious Diseases (USAMRIID), CDC-USA, among others (**Table 3**)

**Table 3: Authors that contributed to at least seven of the 100 top-cited EVD studies**

Rank	Author	Author's Affiliation	Number of studies	1st author	2nd author	3rd or Last author	Total citations
1	Geisbert TW	USAMRIID	13	5	4	4	3923
2	Sanchez A	CDC-USA	13	3	2	8	3561
3	Rollin PE	CDC-USA	12	0	3	9	3310
4	Jahrling PB	USAMRIID	11	2	0	9	2796
5	Peters CJ	USAMRIID	11	0	0	11	2622
6	Nichol ST	CDC-USA	10	0	0	10	2558
7	Gunther S	Bernhard Nocht Inst Trop Med-Germany	8	0	0	8	2731
8	Hensley LE	USAMRIID	8	0	3	5	2130
9	Ksiazek TG	CDC-USA	8	1	0	7	2026
10	Geisbert JB	USAMRIID	7	0	0	7	2028
11	Klenk HD	Philipps University of Marburg Germany	7	0	0	7	2138
12	Volchkov VE	Philipps University of Marburg Germany	7	3	0	4	2022

### Most productive Organisations

The 100 studies were from 271 institutions, and 14 contributed to five or more studies. The leading productive institutions included Centre of Disease Control & Prevention USA (26), US Army of Medical Research Institute of Infectious Diseases (21), Institute Pasteur (10) and World Health Organisation (10), among others. Among African institutions, the International Centre for Medical Research in Franceville Gabon (5) led the list. In addition, Ministries of Health of several EVD endemic African countries also collectively contributed to seven studies, **table 4**.

**Table 4: Institutions that produced five or more of the top-cited EVD studies**

Rank	Institution	Region/Country/location	Number of studies
1	CDC- USA	United States	26
2	USA Med Res Inst Infect Dis	United States	21
3	Institute Pasteur	France	10
4	World Health Organisation	Switzerland	10
5	Harvard University	United States	9
6	University of Marburg	Germany	9
7	University of Pennsylvania	United States	8
8	Ministries of Health	African countries	7
9	Bernhard Nocht Inst Trop Med	Germany	6
10	NIAID	United States	6
11	Ctr Int Rech Med Franceville	Gabon	5
12	Public Health Agency of Canada	Canada	5
13	Public Health of England	United Kingdom	5
14	University of Manitoba	Canada	5

### Most crucial Research fields and Funding institutions

The top cited studies belonged to 17 research fields according to the Web of Science categories, and 12 fields had 4 or more studies. The most popular research field was “Multidisciplinary Sciences” with 24 studies, followed by “Virology” and “Medicine General Internal” with 23 and 20 studies respectively. **(Figure 4a)**

The studies were funded by 55 organisations, and 9 institutions financed 3 or more studies. Most of these were USA institutions and included the United States Department of Health Human Services (n=30), National Institutes of Health NIH USA (28), National Institute of Allergy Infectious Diseases NIAID (17), amongst others. **(Figure 4b)**

(a)

(b)

**Figure 4:** Most crucial Research fields and Funding institutions. (a) Research fields with atleast four studies. (b) Institutions that financed three or more ebola studies

### Analysis of keywords

The studies all together had 48 author keywords and 368 keywords plus. Ten keywords plus appeared more than 8 times, as shown in **Figure 5(a)**. Co-occurrence analysis showed “hemorrhagic fever” as the most co-occurred keyword plus with 24 occurrences, 21 links and 54 total link strength. This was followed by “infection”, “Marburg virus” and “disease”, among others (**Figure 5 (b)**). Note that a minimum of 5 occurrences was set and 27 keywords plus met the threshold.

(a)

(b)

**Figure 5:** Analysis of Keywords. (a) Keywords plus with eight or more occurrence. (b) Overlay visualisation of keywords plus based on occurrence.

### Possible Factors influencing the number of citations

The correlation was also calculated to evaluate the potential relationships between the number of citations and the number of authors, journals’ productivity, and years since publication, and countries involved. Significant correlations were noted between the number of citations and the journal’s *h*-index ( $r=0.86$ ,  $P<0.0004$ ), the impact factor ( $r=0.59$ ,  $P=0.0446$ ), and the number of countries per study ( $0.86$ ,  $P=<0.0001$ ) (**Table 5**).

**Table 5: Factors affecting the number of citations**

Factor	Spearman’s r	P value
Journal <i>h</i> - index	0.86	0.0004
Journal impact factor	0.59	0.0446
Years since publication	0.31	0.1139
Number of countries	0.86	<0.0001
Number of authors	0.03	0.7657

## Discussion

The present study is the first bibliometric study summarising several features of the most influential studies on Ebola. Understanding the characteristics of these studies may be valuable since these studies cover essential advancements in the ebola field.

In this analysis, the 100 top-cited studies were conducted in a period of 40 years between 1977 and 2017, with citations ranging from 169 to 808. Compared to other health fields like Cancer [22] and vaccines [17], the citations of Ebola studies are less, possibly due to less novelty of this topic in the developed countries. The year of 1999 witnessed the most significant advancements in ebola research with 13 most cited studies. Most of these studies focused on identification and characterisation of the Ebola viruses

[23, 24], as well as treatment [25, 26], prevention and control of Ebola outbreaks [27, 28]. Although several recognisable studies have been done since the late 1970s, of which most of them provide recommendations on prevention and control of EVD, Africa in particular still faces recurrent outbreaks of EVD, with the most recent being the 2018–2019 Kivu outbreak. This raises an intriguing question on whether African countries learn from the past outbreaks and effectively implement these recommendations. Besides, Aylward et al. had the most cited study and the highest citations could be because it was the first study to account for and give a general insight into the 2014–2016 Ebola outbreak epidemic in West Africa, which is the biggest EVD outbreak in history [10]. So most of the studies that proceeded cited Aylward's study as one of their references.

The study revealed that most of the top productive journals were virology/ infectious disease-specific journals which implies that the 100 top-cited ebola studies were mostly published in subject-specific journals rather than just high impact factor journals. However, it was noted that no single African journal published any of the top-cited Ebola studies. Given the fact that citation score is the most used index for recognition of published studies, this reveals that despite EVD being endemic to Africa, most, if not all, of the top quality studies are published in foreign journals. Moreover, the accessibility to these journals by African scientists and community, in general, is questionable. This could suggest that the control and prevention recommendations made from these studies just remain on paper/online if not fully accessed by African communities.

The 100 most-cited studies were produced in collaborations among different authors, countries and institutions. The analysis revealed that most of the productive authors are Western or foreign scientists, mainly from the USA and Germany. This questions the active role of African scientists in the top recognised studies, especially in the field of infectious diseases, which is the most significant public health challenge of Africa. Moreover, the USA was the most productive country contributing to 63 studies, followed by Germany and Gabon. The dominance of USA is also highlighted in other research fields [29]. Although several African countries including Guinea, South Africa and Gabon had a significant contribution, it was mainly in collaboration with other countries, with only two single-country studies from Africa. In one perspective, this would imply the role of collaborative efforts and partnerships in achieving research advancements in this field. However, African countries need to set up and strengthen their own research facilities to enable them to carry out independent and recognisable research.

In addition, these studies were mainly produced by US and European institutions, with only one African institution singly contributing to five studies. Although the role of international agencies like WHO and governments of the EVD affected countries, including their ministries of health cannot be underestimated, it is not exhaustively reflected in the top-cited ebola studies. Besides, the funding of these studies also mainly came from USA institutions, which included the US Department of Health Human Services and NIH-USA. Therefore public institutions in Africa and governments, in general, should increase their involvement and funding of clinical research as well as the publication of findings. This would enable evidence-based policy and decision making, especially when it comes to managing and controlling infectious diseases.

The analysis of keywords showed that the studies covered various key aspects of Ebola research, including laboratory studies of the virus, its origin, transmission, as well as infections and outbreaks. Hemorrhagic fever is also highlighted as the keyword with most co-occurrence among the ebola studies. This is due to the characteristic hemorrhagic manifestation of EVD [2, 6], and so the term appears in most of the top-cited studies. However, studies examining the effect of EVD in particular groups of people like pregnant mothers and children were not reflected in keyword analysis nor in the research fields. This field should be thoroughly researched on to enable formulation of targeted interventions in future outbreaks.

Like other previous bibliometric analyses, our study also has some limitations [16, 17]. First, citation analysis was based on one database, the Web of Science; thus, some essential papers indexed by other databases might have been missed [16, 22]. The citation numbers therefor might be misleading [30], owing to self-citations, time of publications, among other factors. Thus, further studies are required using different databases to validate these findings. However, it should be noted that although citation analysis is a good measure of recognition, it is not the best index for evaluating quality or importance of scientific research [22]. Besides, since old studies have more citation than new ones, citation analysis tends to undervalue newly published studies, for example, the achievements in EVD vaccine development within the recent years are not captured in this analysis.

## **Conclusions**

The study has characterised, and provided insights into the historical advancements of EVD research reflected through the 100 top-cited studies. The study has highlighted the leading roles played by various stakeholders, as well as the collaborative efforts exhibited not only among authors but also among countries and institutions in addressing EVD. Besides, the study has revealed that Africa's role in Ebola research is lacking. Thus there is a need for African countries to invest more in clinical research and to strengthen local publication databases and journals. This would facilitate dissemination as well as more access to the valuable information contained in such prestigious studies. Given the infectiousness and severity of EVD, it remains a significant research area calling for a collaborative response, especially in times of outbreaks.

## **Declarations**

### **Author Contributions**

Conceptualisation was done by J.K and X.J.U, the methodology by X.J.Y, while T.H.M, J.K, and UG performed data visualisation and formal analysis. J.K, ON, and SSP wrote and prepared the original draft, KJ, UG, SSP, ON and T.H.M wrote, reviewed and edited the manuscript. X.J.Y supervised the study. All the authors have read and agreed to the published version of the document.

### **Funding**

None

## Availability of data and materials

All the data supporting the results of this study are included in the article and the supplementary file. The raw data can also be directly obtained from the Web of Science Core Collection using the appropriate search query.

## Ethics approval and consent to participate

No ethical approval was required since the data used was from a public database, and no human or animal subject was directly involved.

## Consent for publication

Not applicable

## Conflicts of Interest

The authors declare no conflict of interest.

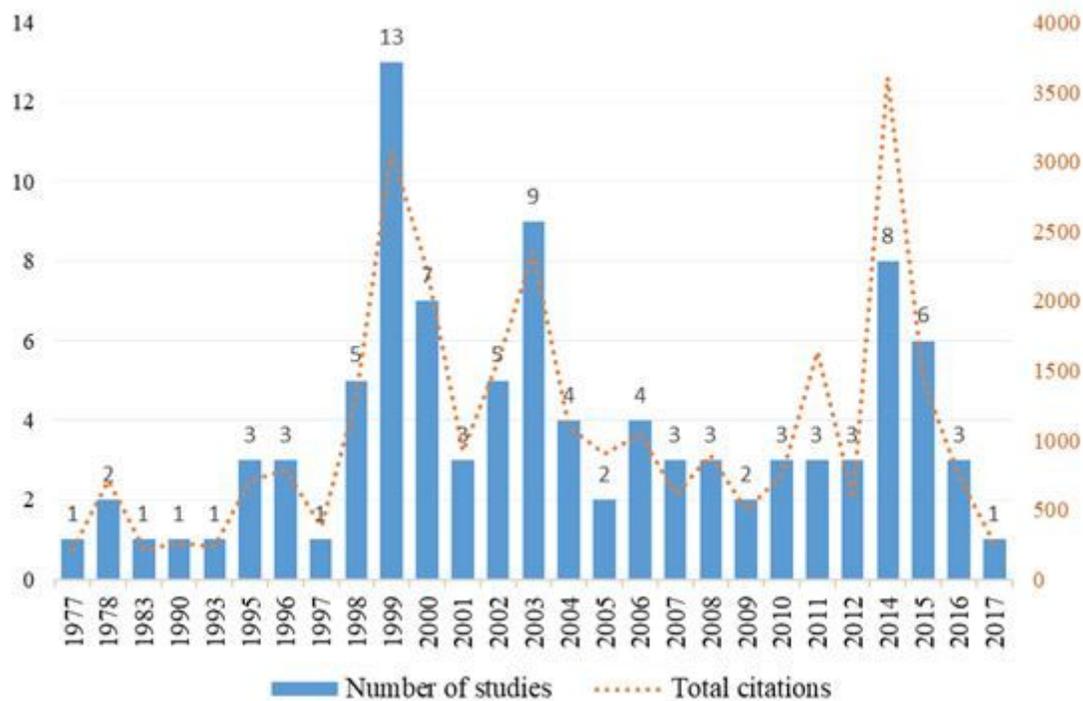
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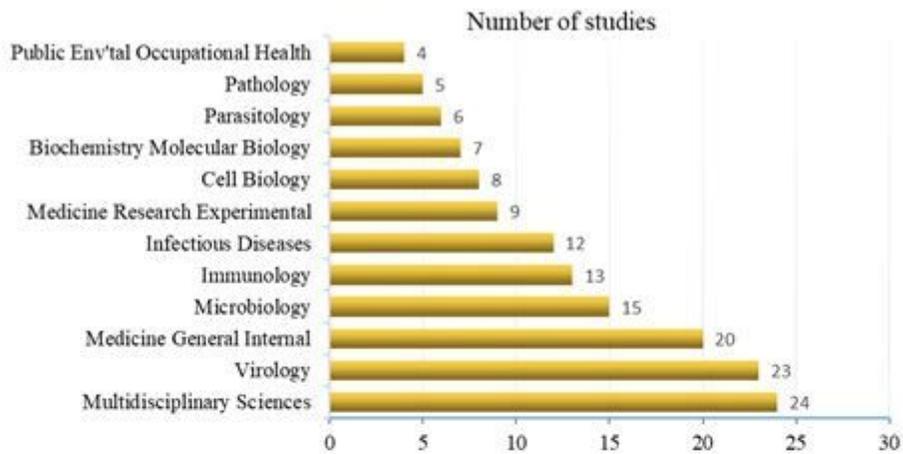
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## Figures

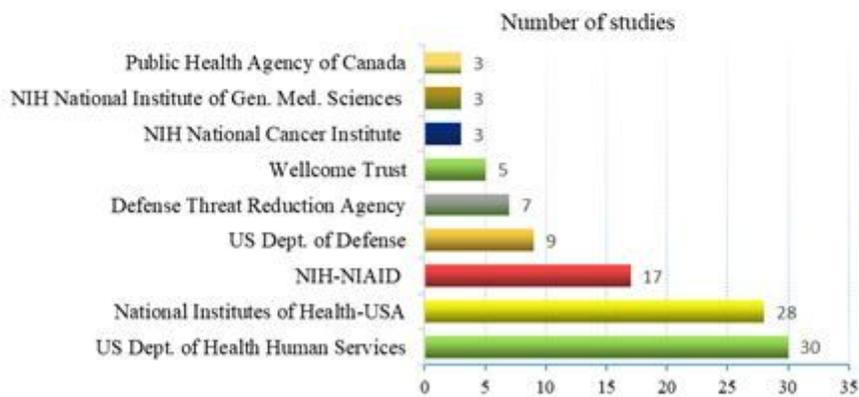


**Figure 1**

Annual trend and citation of EVD publications (1977 to 2017)



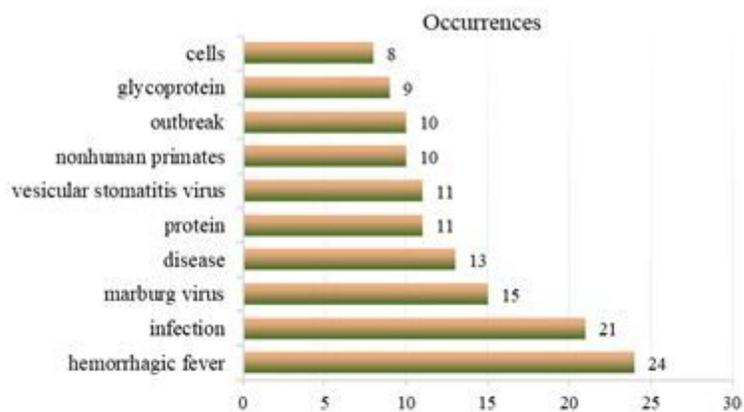
(a)



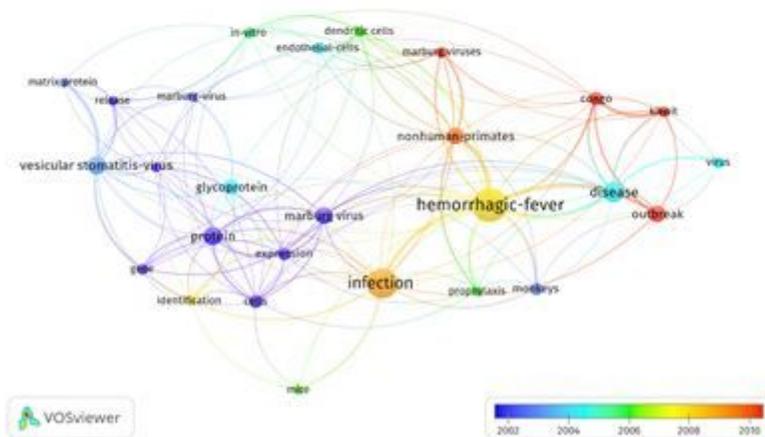
(b)

**Figure 2**

Most crucial Research fields and Funding institutions. (a) Research fields with atleast four studies. (b) Institutions that financed three or more ebola studies



(a)



(b)

### Figure 3

Analysis of Keywords. (a) Keywords plus with eight or more occurrence. (b) Overlay visualisation of keywords plus based on occurrence.

## Supplementary Files

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