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Original Article

Global research profile on monkeypox-related literature (1962–2022): A bibliometric analysis

Fajar Sofyantoro[1], Hendrix I. Kusuma[2,3,4], Sandro Vento[5], Marius Rademaker[6] and Andri Frediansyah[7*]

[1]Department of Tropical Biology, Faculty of Biology, Universitas Gadjah Mada, Yogyakarta, Indonesia; [2]Medical Research Unit, School of Medicine, Universitas Syiah Kuala, Banda Aceh, Indonesia; [3]Department of Biology, Faculty of Mathematics and Natural Sciences, Universitas Syiah Kuala, Banda Aceh, Indonesia; [4]Department of Biology Education, Faculty of Tarbiyah and Teacher Training, Universitas Islam Negeri Ar-Raniry, Banda Aceh, Indonesia; [5]Faculty of Medicine, University of Puthisastra, Phnom Penh, Cambodia; [6]Clinical Trial New Zealand, Waikato Hospital Campus, Hamilton, New Zealand; [7]PRTPP, National Research and Innovation Agency (BRIN), Yogyakarta, Indonesia

*Corresponding author: andri.frediansyah@brin.go.id

Abstract

The recent monkeypox or mpox outbreak has been a global concern. The present study evaluated the global research outputs, research trends, and topics of published research on monkeypox using a bibliometric approach. The Scopus database was searched for terms associated with "monkeypox" or "monkey pox" up until 19 November 2022. Maps and bibliometric indicators of the retrieved documents were shown and analyzed. A total of 1,422 documents were obtained from Scopus. Other than monkeypox, the most commonly used terms included epidemic, disease outbreaks, smallpox vaccine, and orthopoxvirus. In total, 90.3% of the documents were published between 2002 and 2022. The United States, the United Kingdom, and India were the top three countries in terms of productivity. Most of the institutions were from the United States. The International Journal of Surgery, the Journal of Medical Virology, and the Travel Medicine and Infectious Disease are some of the top journals currently publishing research on monkeypox. Tecovirimat, coronavirus disease 2019 (COVID-19), homosexuality, and pandemic are emerging topics related to monkeypox.

Keywords: Monkeypox, bibliometric research, epidemic, disease outbreak, mpox

Introduction

The *Orthopoxvirus*, a genus belonging to the *Poxviridae* family, includes various well-characterized zoonotic viruses, including smallpox, vaccinia, cowpox, and monkeypox [1-4]. Rodents and non-human primates are reported to be the main hosts for poxviruses [2, 5-7]. Poxviruses can be tranmitted to humans, resulting in cases of animal-to-human and then human-to-human transmission [2, 7-9]. Despite smallpox being eradicated in the 1970s, it became apparent that smallpox-like illnesses were still occurring in rural areas, leading to the recognition of monkeypox as a unique disease [10-14]. Many of the clinical features of monkeypox, caused by monkeypox virus, resemble those of smallpox [15-17]. Due to a 2003 outbreak in the United States, monkeypox gained attention as a disease of potential global public health relevance [14, 18-20]. Since then, multiple monkeypox outbreaks have been recorded worldwide, including a large outbreak in Nigeria in 2017 [21-25].

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The first case of monkeypox was reported in Denmark in a colony of macaques [26, 27]. In 1970, the Democratic Republic of the Congo reported its first human case of monkeypox [28]. Monkeypox virus can infect humans, resulting in animal-to-human and then human-to-human transmission [7, 15, 29-31]. Even though the host of monkeypox virus remains unclear, rodents are considered as one of the possible reservoirs [14, 20, 32-36].

Several routes of transmission for the monkeypox virus have been proposed, including direct contact or exposure to body fluids of infected individuals or animals [27, 31, 37–40]. Similar to smallpox, the infection of monkeypox virus starts with virus attachment to the respiratory surface of the hosts. During the 7–21 days of incubation, the monkeypox virus circulates to lymph nodes [24, 30, 31, 41].

Symptoms of monkepox disease begin to appear after the incubation stage, followingvirus spreading from lymphoid tissue to skin and other organs. In addition to nonspecific symptoms including fever and rash, common symptoms are muco-cutaneous lesions and lymphadenopathy [42–44]. Currently, the antipox viral agent tecovirimat, known to be effective in treating smallpox, has been recommended for individuals with symptoms of monkeypox disease [45–48].

A review of the literature and trends in monkeypox-related research is indicated due to the rapid global spread of monkeypox disease [23, 49, 50]. Numerous indicators should be evaluated in a bibliometric analysis, to allow for analysis of various metrics and patterns [51, 52]. The data collected in this current study presents a clear image of the progress in monkeypox research, which may help researchers to identify impacts from countries, authors or institutions, journals, and keywords [53, 54]. These quantitative parameters, together with other variables and infometrics investigated in the present study, can be used to evaluate the productivity of monkeypox research [53, 55].

Bibliometric analysis offers an overview of a vast body of literature and serves as a useful tool for tracking the development of worldwide trends. Additionally, it offers empirical support that enables to evaluate the influence of research publications in various fields [56–58]. Bibliometric analysis is also increasingly being employed as prime source for policy-making [59–61]. Therefore, the primary objective of the current study is to examine the developments in research on monkeypox from 1962 to 2022, highlighting emerging subjects, gaps in knowledge, and patterns of collaboration.

Methods

A single database is typically utilized in bibliometric studies to retrieve the literature for quantitative and qualitative analyses. Scopus database was employed in this study since it provides a number of advantages over other databases (e.g., Medline or Web of Science). Scopus indexes a greater number of documents than Web of Science or Medline, including journals in medicine, social studies, engineering, and scientific fields [62, 63]. The search strategy was based on the title search using as keywords "monkeypox" OR "monkey pox". Documents published up to 19 November 2022 were included. The search algorithms excluded erratum and imposed no language restrictions. The retrieved documents were examined for the occurrence of false-positive results. Similar to previous studies, false positives were screened by manually examining 10% of the retrieved papers [64]. As a result, no false-positives were identified.

Bibliometric criteria and mapping were analyzed together with the acquired documents. The number of citations, the productivity of publishing countries and institutions were also collected. Documents with authors from several countries were referred to as "multiple country publications". The number of publications was plotted in 1-year time- periods to show the growth of publications. The VOSviewer software was used to map out and visualize the results [65]. In addition, a network visualization map representing the most popular keywords was generated. The size of each node on this map represents how frequently the keyword appears. A network visualization map was also used to analyze international collaboration among researchers. The strength of the collaboration was indicated by the size of the connecting line.

Results

A total of 1,422 documents in monkeypox-related research published between 1962 to 2022 were identified from the Scopus database. The retrieved documents contained texts in 11 different languages; the most common language was English (n=1333; 93.7%), followed by French (n=33; 2.3%), and Spanish (n=22; 1.5%). Research articles (n=767; 53.9%) made up the majority of the documents, followed by letters (n=280; 19.7%), and reviews (n=141; 9.9%). As shown in **Figure 1**, in addition to the default term "monkeypox," the most often occurring keywords according to the analysis included epidemic (n=417), disease outbreaks (n=316), smallpox vaccine (n=233), and orthopoxvirus (n=208). The overlay visualization revealed that phrases such as tecovirimat, COVID-19, homosexuality, and pandemic appeared in documents published after 2020 (**Figure 2**).

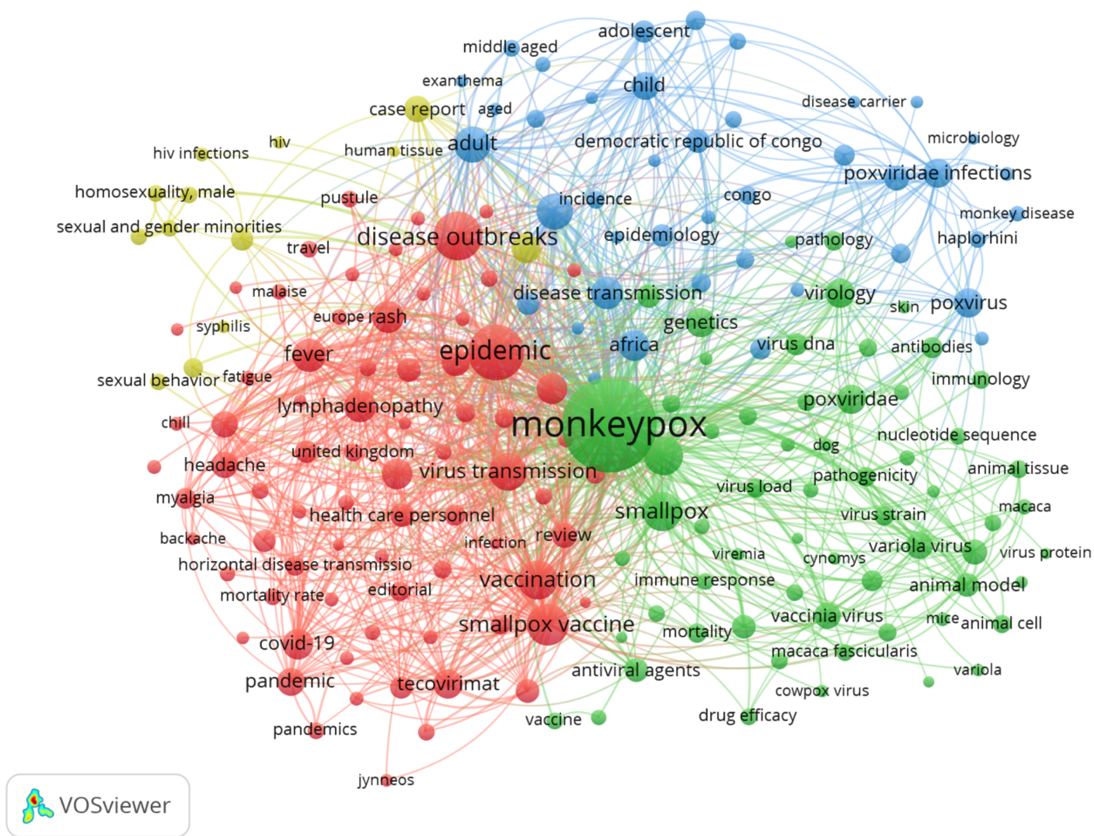

Figure 1. VOSviewer mapping of keywords co-occurrences extracted from the retrieved documents. The minimum limit was established at 20 occurrences, resulting in 201 keywords. Each cluster was assigned a different color. The size of the circles represents the frequency of occurrence of a term. Each cluster displayed terms that were relatively close and linked, as indicated by their co-appearance in the retrieved documents.

Few monkeypox-related documents were published prior to 2002. The number of manuscripts published between 2002–2022 account for 90.3% (n=1284), with most having been published in the last 12 months (n=953; 67.01%) (**Figure 3**). The retrieved documents were cited 20,519 times, averaging 14.42 citations per document. As of 19 November 2022, a total of 587 (41.3%) manuscripts have not yet been cited.

Table 1 displays the top ten cited articles, including two reviews and eight research papers. The most productive countries in terms of publishing research on monkeypox are listed in **Table 2**. The top-ranking country with 33.3% of the documents (n=474) was the United States, followed by the United Kingdom (n=140; 9.8%).

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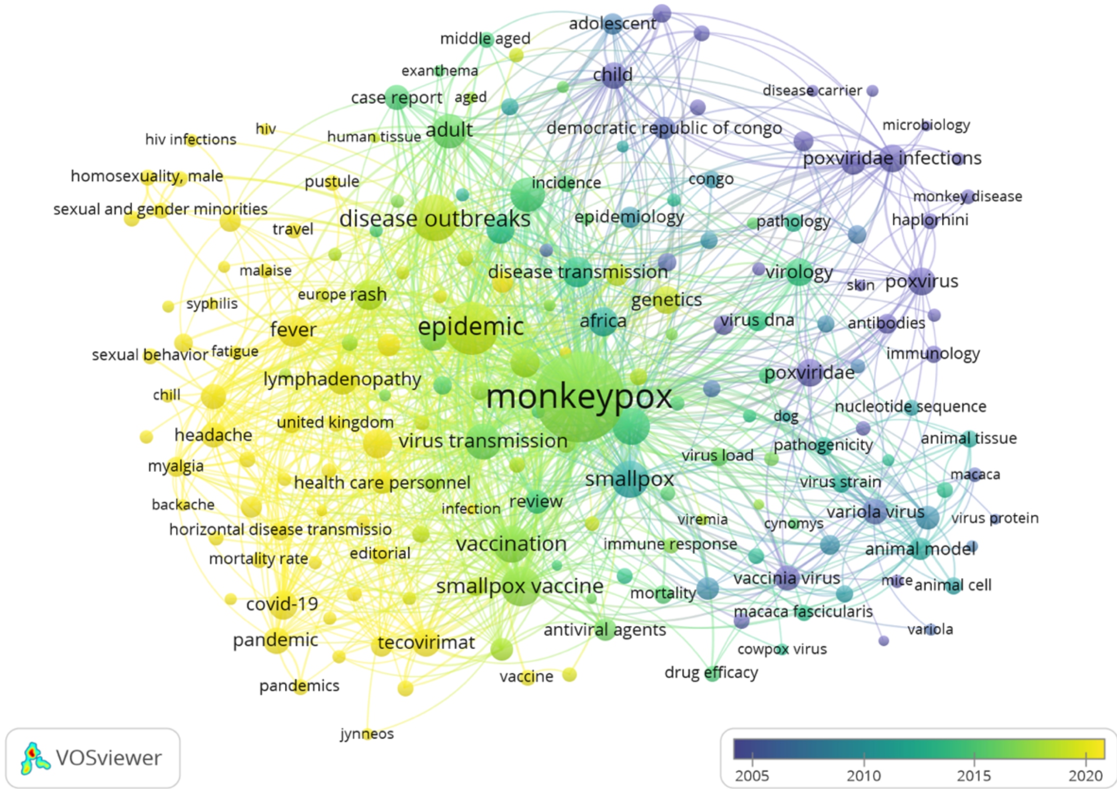

Figure 2. Overlay of VOSviewer keywords co-occurrences mapping. The minimum limit was established at 20 occurrences, resulting in 201 keywords. The year of appearance was indicated by color gradation from purple to yellow.

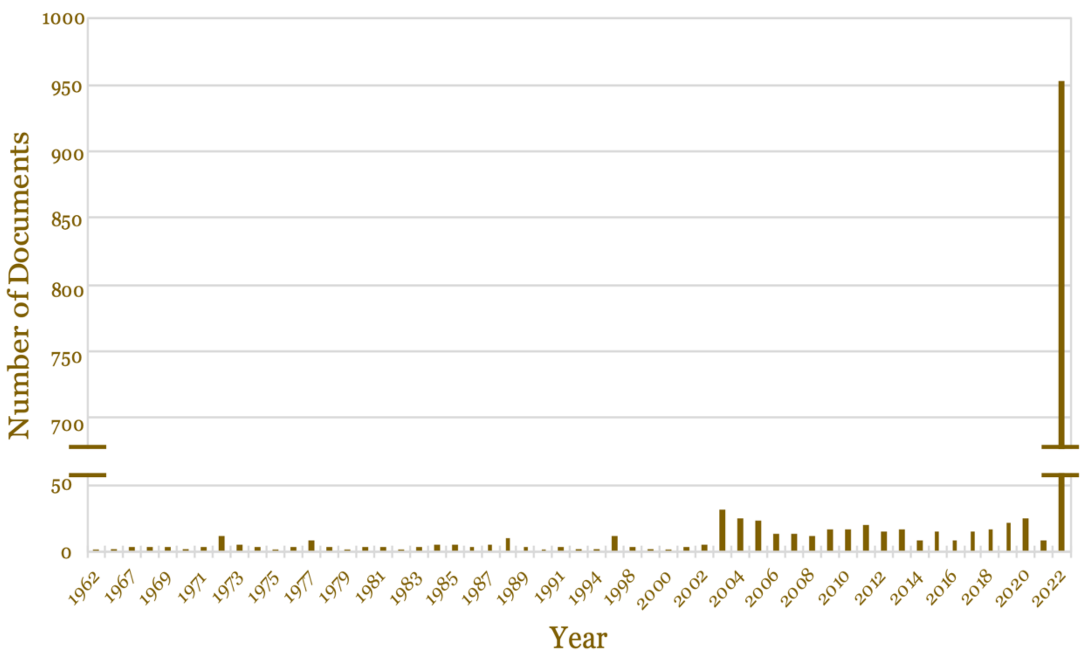

Figure 3. Annual productivity of scientific publications in monkeypox-related research from 1962–2022.

Table 1. Top ten cited research documents related to monkeypox

No	Author(s)	Title	Year	Journal	Citations	Type of documents
1	Reed *et al* [19]	The Detection of Monkeypox in Humans in the Western Hemisphere	2004	New England Journal of Medicine	449	Article
2	Rogers *et al* [66]	A preliminary assessment of silver nanoparticle inhibition of monkeypox virus plaque formation	2008	Nanoscale Research Letters	330	Article
3	Earl *et al* [67]	Immunogenicity of a highly attenuated MVA smallpox vaccine and protection against monkeypox	2004	Nature	292	Article
4	Rimoin *et al* [12]	Major increase in human monkeypox incidence 30 years after smallpox vaccination campaigns cease in the Democratic Republic of Congo	2010	Proceedings of the National Academy of Sciences of the United States of America	291	Article
5	Di Giulio and Eckburg [68]	Human monkeypox: An emerging zoonosis	2004	Lancet Infectious Diseases	277	Review
6	Bunge *et al* [15]	The changing epidemiology of human monkeypox—A potential threat? A systematic review	2022	PLOS Neglected Tropical Diseases	261	Review
7	Hutin *et al* [69]	Outbreak of human monkeypox, Democratic Republic of Congo, 1996 to 1997.	2001	Emerging Infectious Diseases	259	Article
8	Likos *et al* [70]	A tale of two clades: Monkeypox viruses	2005	Journal of General Virology	248	Article
9	Edghill-Smith *et al* [71]	Smallpox vaccine-induced antibodies are necessary and sufficient for protection against monkeypox virus	2005	Nature Medicine	223	Article
10	Adler *et al* [45]	Clinical features and management of human monkeypox: a retrospective observational study in the UK	2022	The Lancet Infectious Diseases	209	Article

Table 2. Top ten countries publishing documents related to monkeypox

No	Country	Number of documents	Percentage
1	United States	474	33.3
2	United Kingdom	140	9.8
3	India	114	8.0
4	Germany	71	5.0
5	Italy	69	4.9
6	China	68	4.8
7	Nigeria	63	4.4
8	Pakistan	53	3.8
9	France	52	3.7
9	Switzerland	52	3.7

Countries with equal number of documents were designated with the same rank.

Figure 4 displays the visualization of global collaboration among countries with a minimum number of of 30 published documents. The relative strength of research collaboration is indicated by the thickness of the connecting line between any two countries. The link strength between the United States and the Democratic Republic of the Congo was 39, whereas the link strength between the United States and Spain was 4, showing that there are more cooperative research projects between the United States and the Democratic Republic of the Congo than between the United States and Spain.

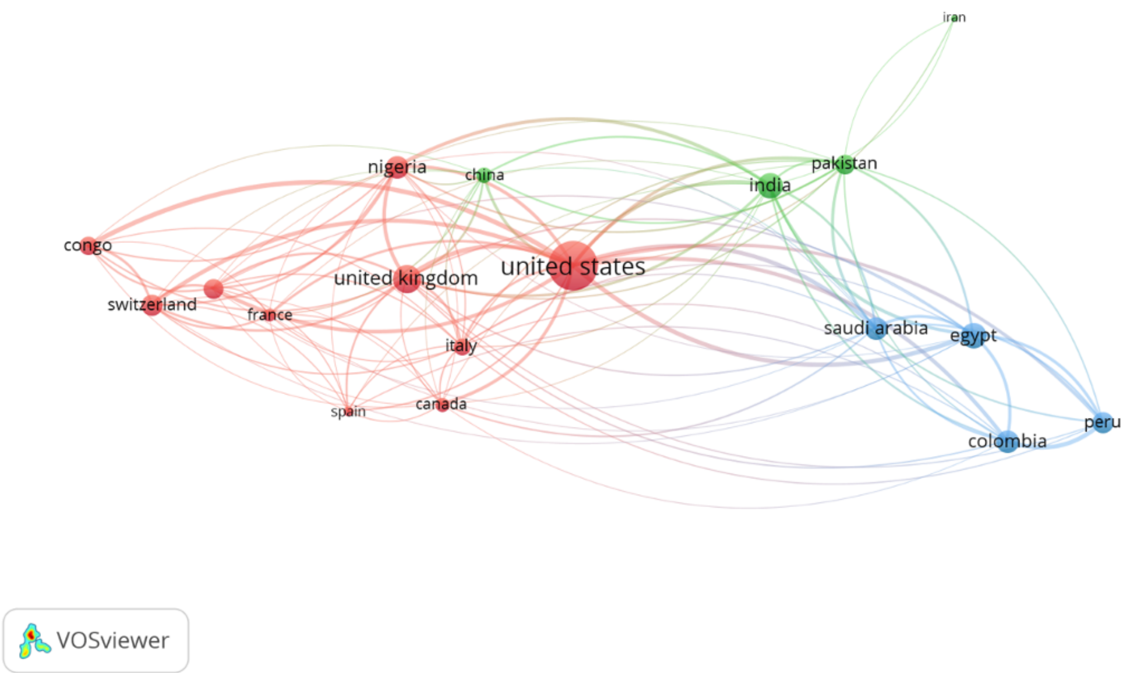

Figure 4. Mapping of international research collaboration. The minimum number of articles was 30 articles, resulting in 18 countries.

The Centers for Disease Control and Prevention (n=118; 8.3%) took the first place in the list of the most prolific institutions, followed by the World Health Organization (WHO) (n=45; 3.2%), and the US Army Medical Research Institute of Infectious Diseases (n=40; 2.8%) (**Table 3**). **Table 4** displays the top ten active authors. The top three authors were Damon, I.K. (n=61; 4.3%), Reynolds, M.G. (n=39; 2.7%), and McCollum, A.M. (n=32; 2.3%). In **Table 5**, the top ten journals for publishing research on monkeypox are presented. The International Journal of Surgery (n=53; 3.7%) came in first in terms of the quantity of documents published, followed by the Journal of Medical Virology (n=48; 3.4%), and the Travel Medicine and Infectious Disease (n=47; 3.3%).

Table 3. Top ten institutions with the highest productivity

No	Institution	Country affiliation	Number of documents (%)
1	Centers for Disease Control and Prevention	United States	118 (8.3)
2	Organisation Mondiale de la Santé (World Health Organization)	Switzerland	45 (3.2)
3	U.S. Army Medical Research Institute of Infectious Diseases	United States	40 (2.8)
4	National Institute of Allergy and Infectious Diseases (National Institutes of Health)	United States	38 (2.7)
5	Harvard Medical School	United States	32 (2.3)
6	Universidad Cientifica del Sur	Peru	27 (1.9)
6	Fundación Universitaria Autónoma de las Américas	Colombia	27 (1.9)
7	Tribhuvan University	Nepal	25 (1.7)
8	Emory University	United States	23 (1.6)
9	Nigeria Centre for Disease Control	Nigeria	20 (1.4)

Institutions with equal number of documents were designated with the same rank.

Table 4. Top ten authors publishing documents related to monkeypox

No	Author	Number of documents (%)
1	Damon, I.K.	61 (4.3)
2	Reynolds, M.G.	39 (2.7)
3	McCollum, A.M.	32 (2.3)
4	Carroll, D.S.	28 (1.9)
5	Karem, K.L.	26 (1.8)
6	Li, Y.	24 (1.7)
6	Olson, V.A.	24 (1.7)
7	Sah, R.	22 (1.6)
8	Rodriguez-Morales, A.J.	21 (1.5)
9	Wiwanitkit, V.	20 (1.4)

Researchers with equal number of documents were designated with the same rank.

Table 5. Top ten journals publishing monkeypox-related research

No	Journal title	Number of articles (%)	Impact factor (2021)
1	International Journal of Surgery	53 (3.7)	13.40
2	Journal of Medical Virology	48 (3.4)	20.69
3	Travel Medicine and Infectious Disease	47 (3.3)	6.21
4	Annals of Medicine and Surgery	37 (2.6)	-
4	Emerging Infectious Diseases	37 (2.6)	16.16
5	Lancet Infectious Diseases	27 (1.9)	71.42
6	Lancet	24 (1.7)	202.70
7	Journal of Virology	22 (1.5)	4.43
8	Bulletin of the World Health Organization	21 (1.4)	9.40
8	Eurosurveillance	21 (1.4)	6.30

Journals with equal number of documents were designated with the same rank.

Discussion

Our study presented a comprehensive analysis to evaluate the progress of global monkeypox-related research. The current study revealed a notable increase in publications in the last two decades, but more so in the last 12 months. The search strategy and approach adopted in this research ensured the validity of the data extracted from Scopus as the largest database of scientific documents. Since Scopus database favors English journals, research documents published by developing nations in non-English publishers may have been underrepresented. The majority of Scopus-indexed journals are from the United States, the United Kingdom, and other countries with English as the main language in scientific endeavors. As a result, statistics regarding institutions and authors may be biased in favor of countries where the Scopus-indexed journals are published.

The recent developments of monkepoy outbreaks and the inclusion of monkeypox as a chronic disease may be partially responsible for the considerable increase of publications in recent years. As of 19 November 2022, there were 953 (67.0%) articles published in 2022 only. The most numerous contributions to the field have come from authors and institutions in North America and Europe. The large research budgets available in North America and Europe may have contributed to the United Kingdom and the United States productivity in monkeypox-related studies. Additionally, the large number of researchers and research institutions also contributes to the high productivity. A number of earlier bibliometric studies showed a similar distribution, demonstrating that high-income countries are the dominant players in scientific publications [72-75]. However, China is absent from the top five of the most productive countries. It is probable that several monkeypox-related documents published by China have been excluded due to the low number of Chinese medical journals indexed in Scopus. There was one country from Africa listed among the top 10 productive countries, reflecting the high prevalence of monkeypox in that continent. However, the lack of resources and the language barrier might impede the advancement of this field of research in Africa. Therefore, to increase the research productivity in countries with limited resources, research collaborations in the field of monkeypox-related studies needs to be expanded [76].

Compared to our study, previously published bibliometric studies on monkeypox only focused on literature published in English between 1990–2022, possibly neglecting the contribution of non-English countries or journals [77]. Also, another independent group published bibliometric analysis using “monkeypox” as the sole keyword [78], hence excluding articles containing the alternative form of “monkey pox”. It is to be noted that the current study has a few drawbacks, which were also reported in previously published bibliometric analyses [72, 73, 75]. Since numerous academic and research-based journals are not included in the Scopus index, some articles on monkeypox will have been overlooked. However, we employed the Scopus database as the sole source of documents for this study while taking into account a number of benefits. First, Scopus indexing focuses on respectable and peer-reviewed journals. Therefore, by using Scopus as our source, we eliminated the possibility of including articles published by predatory journals. Second, Scopus offers useful tools like "cited references," which allow researchers to analyze whether other papers have cited a specific article after its publication. Therefore, in light of the aforementioned advantages, we conclude that using the Scopus database as the only source for our bibliometric study was acceptable. Another possible limitation of the current study is related to the use of the title search strategy, rather than the title/abstract/keyword. To some extent, the title search method in our manuscript might result in the omission of some documents. However, the title search approach was preferred rather than the title/abstract/keyword strategy since it significantly reduced the number of false-positive results.

Conclusions

Our current study provides a thorough bibliometric analysis of literature related to monkeypox. In terms of the volume of documents and international cooperation, the United States was the most significant contributor. Since 2003, a gradual increase in the quantity of published papers was observed, and high numbers were published from the beginning of 2022.

Ethics approval

Not Applicable

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Conflict of interest

All the authors declare that there are no conflicts of interest.

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Underlying data

All data underlying the results are available as part of the article and no additional source data are required.

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