Elsevier has created a Monkeypox Information Center in response to the declared public health emergency of international concern, with free information in English on the monkeypox virus. The Monkeypox Information Center is hosted on Elsevier Connect, the company's public news and information website.

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Concern over monkeypox outbreak: What can we learn from the top 100 highly cited articles in monkeypox research?

Dear Editor,

Recently, the sudden emergence and transmission of monkeypox (MPX) reported in European and American countries has caused concern in the public health community worldwide [1]. MPX is a zoonotic disease caused by monkeypox virus (MPXV), a member of the orthopoxvirus genus. Although MPXV is less fatal and not as highly transmissible as smallpox virus, it remains the only poxvirus causing significant mortality in humans since smallpox eradication. Since 2003, MPX has gained increased attention owing to an outbreak in the USA, and there are constantly new studies being published on this topic [2]. Generally, citation number is often recognized as an important index for evaluating the relative impact of published documents, and the 100 highly cited articles are commonly referred to as "citation classics", that could provide value information on research hotspots of a given field. To our knowledge, there has been no published work on summarizing the top 100 most cited studies in the field of MPX.

The top 100 most cited studies on MPX were retrieved from Web of Science Core Collection on May 22, 2022. Data were collected based on the following strategy: TS=(monkeypox OR "monkey pox"). All the retrieved records were placed in descending order according to the citation number. Full texts and abstracts were screened by two researchers (CKM and ZY) independently to confirm if it should be included. Microsoft Excel 2019 and VOSviewer software were used for data analysis and visualization. Specific information of the top 100 most cited studies is summarized in Supplementary Table 1.

As shown in Fig. 1A, these 100 most cited studies were published between 1980 and 2018, and the years that yielded the relatively large number articles were around 2004, which is in line with the first outbreak in the USA. The citation frequency for each article ranged from 48 to 465 (mean: 107.27). In comparison with bibliometric studies of other fields, the overall citation frequency is not high, indicating that this area had not received much attention previously [3].

A total of 19 countries contributed to the top 100 highly cited articles. Of them, the USA dominated the area with 77 documents, followed by Switzerland, Germany and Democratic Republic of the Congo (Fig. 1B and Supplementary Fig. 1A). Undoubtedly, the USA is the most influential country in this domain. As for reasons, it cannot be separated from the contribution from these high-impact institutions, scholars, and sufficient financial support. Specifically, US-CDC was the institution with the most top-cited articles (32 documents). As for authors, three quarters of authors with more than 6 studies are from the USA. The most frequently nominated author was Damon IK from US-CDC, and of the top 100 articles, 21 listed her name. In the case of the funding organizations, in addition to WHO, these from the USA including CDC, NIH, and NIAID, occupied the top four positions contributed to MPX research. In addition, the network visualization maps of country or author co-authorship analysis were generated (Supplementary Fig. 1A and Supplementary Fig. 2). With these knowledge maps, we could clearly understand the cooperation relationships between countries/authors.

The 100 most cited studies were published in 52 different journals (Fig. 1C). Among them, *Journal of Infectious Diseases*, *Journal of Virology*, And *Virology* were leading journals with 6 published studies. As for journal co-citation analysis in Supplementary Fig. 3, *Journal of Virology*, And *Virology* hold the greatest influence with most citations. Moreover, based on subject categories, WoSCC could assign all these studies to different research areas. As shown in Fig. 1D, apart from Microbiology, Virology, and Infectious Diseases, Immunology, Biochemistry & Molecular Biology, and Public Environmental Occupational Health are also the research areas received the most attention.

As shown in Supplementary Figs. 4A and 4B, keywords co-occurrence analysis was conducted by VOSviewer. The average appearing year and the occurrence of a keyword could reflect the research focuses in different periods. It can be seen that apart from MPX, other orthopoxvirus genus such as smallpox virus, vaccinia virus, and cowpox virus also had higher occurrence frequencies, indicating a close research linkage among these viruses. Additionally, we cluster all these studies based on their research directions. Of them, 23% were published as review articles, and the remaining 77% were research articles or letters. Of these reviews, many researchers have summarized the epidemiology, hosts and reservoirs, transmissibility, lethality, clinical characteristics, diagnosis, treatment and prevention in detail. In sum, these reviews contribute to the understanding of the existing knowledge about the MPX and could provide researchers more complete understanding of the landscape of this field. As for these 77 research articles and letters, vaccine studies such as smallpox DNA vaccine, highly attenuated vaccinia virus vaccine, is one of the most concerned topics in this field, and 15 studies have dealt with the protection efficacy and immunogenicity of different vaccines. Pervious data indicated that smallpox vaccination (discontinued in 1980) could impart approximately 85% protection against MPX [4]. The surveillance data in Democratic Republic of Congo suggested that a 20-fold increase in

Abbreviations: MPX, monkeypox; MPXV, monkeypox virus; WoSCC, Web of Science Core Collection; WHO, World Health Organization; CDC, Centers for Disease Control and Prevention; NIH, National Institutes of Health; NIAID, NIH National Institute of Allergy Infectious Diseases.

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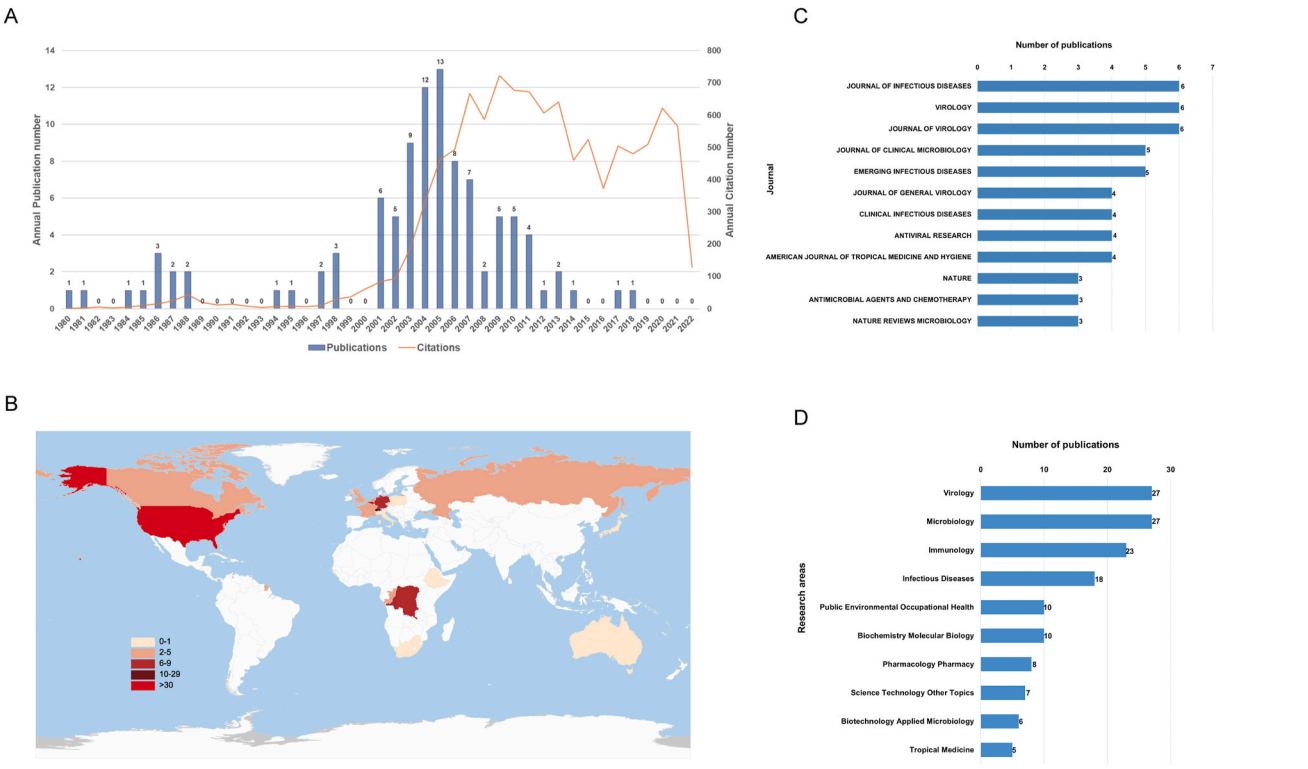

Fig. 1. (A) Number of top-cited publications from 1980 to 2022; (B) Geographical distribution map of top-cited publications related to MPX; (C) Number of top-cited publications by journals (N ≥ 3); (D) Number of top-cited publications by research area (N ≥ 6).

human MPX incidence after 30 years cessation of the smallpox vaccination campaign [5]. Thus, vaccination is still an important approach for the protection of humans against MPX. Besides this, 13 studies introduced epidemiological data, 10 studies addressed the detection and discrimination of MPXV and other orthopoxviruses, and 10 studies addressed the antiviral agents and therapeutics for MPX including ST-246, cidofovir, as well as silver nanoparticles, etc. There are also studies that have analyzed MPXV transmission and pathogenesis (N = 10), MPXV genome (N = 9), clinical manifestations of human MPX (N = 3), animal models (N = 3), MPXV virulence (N = 2), pathology (N = 1), and its potential threat as a biological weapon (N = 1).

This is the first work summarizing the100 highly cited articles regarding MPXV. Although there were two previous bibliometric studies regarding this topic, both studies were based on the all the MPXV-related literature in this domain and they have not specifically focused on the highly cited articles of this field [6,7]. In contrast to previous studies, we provided a more detailed summary and description on the most influential countries, institutions, authors, journals, research areas, as well as research directions in the field of MPXV. To sum up, although the COVID-19 pandemic is still capturing the attention and the most health care resources of the world, the public health organizations must also increase vigilance to MPX through improving surveillance system, building detection capacity, and informing human behaviors to reduce human-to-human transmission. Nevertheless, unlike the sudden outbreak of COVID-19, since the emergence of MPX, there has been a certain amount of research published and our knowledge of this virus has grown. Our data could help researchers to better understand the influential work in the evolution of this field and provide novel insights into to conduct further studies.

Author contributions

Kunming Cheng: Conceptualization, Methodology, Data curation, Writing- Original draft preparation. Qiang Guo: Methodology, Data curation, Data visualization, Writing- Revised draft preparation; Yan Zhou: Conceptualization, Methodology, Data curation, Writing- Original draft preparation. Haiyang Wu: Conceptualization, Methodology, Data curation, Writing- Reviewing and Editing.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.tmaid.2022.102371.

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