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What We Know about Top 1000 Highly-Cited COVID-19 Papers: A Bibliometric Analysis

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Abstract

Background:
Highly cited papers are considered publications with a great impact on a scientific community and have been deeply investigated in different fields.

Aim: This study aimed at analyzing and visualizing the top 1000 highly cited papers on COVID-19.

Methods: As a bibliometric study, this study was conducted by retrieving 1000 highly-cited papers on COVID-19 published during 2019-2021 from Scopus. The search strategy was to obtain 35 related keywords/terms on the COVID-19 as the main term from *MeSH* and searching them in the fields of paper titles, abstracts, and keywords. Bibliometric techniques such as co-citation analysis, co-authorship analysis and word co-occurrence analysis were used for the study. Data visualization was done by applying the VOSviewer software package and GunnMap.

Results: China, the United States of America (USA), and the United Kingdom (UK) with publishing 418, 353, and 149, mostly cited papers were ranked first-to-third, respectively. The top contributing research institutes were from China and the USA. The top three most productive research institutions were Huazhong University of Science and Technology (N=83), Tongji Medical College (N=76), and Wuhan University (N=64), respectively. *The New England Journal of Medicine*, *the Lancet* and *JAMA* ranked first to third in publishing these papers, respectively. Collaborating countries were mainly of European origin. Research institutes from China, the USA, and the UK had higher collaboration. Keyword clustering showed that the clinical features and laboratory descriptions, risk factors, pathogenic and immunological aspects as well as the managerial aspects and urgent preparation of the disease were topics with high concern and concentration.

Conclusion: This study is the first bibliometric study on the top 1000 highly cited papers on COVID-19 and can be beneficial to researchers in identifying important topics, active producing agents and existing gaps in the literature on the disease. It can be conceived as a reference for COVID-19 researchers and a guide for conducting other bibliometric studies on COVID-19 scientific investigation.

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Introduction

The outbreak of Coronavirus Disease 2019 (COVID-19) has been declared to be a public health emergency with international concern and recognized as a pandemic disease1. Recently, it is considered as one of the top research topics in the medical field with its increasing trend in research publication, including that of bibliometric studies.

Bibliometrics as a tool for measuring scientific impact quantifying research performance2 has been widely used for evaluating scientific research in different fields and a variety of aggregate levels (such as papers, journals, authors, research institutions, research topics, countries/regions, etc.). Bibliometric indicators have been widely and increasingly applied in medical fields3.

Highly cited papers are considered publications with a great impact on a scientific community reflecting different aspects of a scientific discipline. Highly cited papers (especially the top 100 most-cited papers) have been widely investigated different bibliometric aspects in medical and non-medical fields. In medical fields, some related studied can be mentioned, including among others, surgery (4), anesthesia5, neurosurgery (6), endodontics (7), pediatric neurosurgery (8), radiology (9), traumatic brain injury (10), tuberculosis (11), coronary heart disease 12, gastroenterology and herpetology (13), acute kidney injury (14), neuroimaging (15), endocrinology and metabolism16, neuroscience17, pulmonary imaging (18), cardiology (19), microbiology (20), obstetrics and gynecology (21), vaccine and vaccination22 Hepatitis E virus (23), digestive endoscopy (24), and raniosynostosis (25).

After the outbreak of COVID-19, some bibliometric studies have been conducted on it in the years 2019, 2020, and 2021, investigating the disease from different perspectives (e.g. 23, 26-39). Top highly-cited and most notable papers on COVID-19 have been included in these studies (e.g. 100 highly-cited / most influential articles about COVID-19 (40-42), most notable and highly-disseminated 100 articles on COVID-19 in social media (43, 44), and 50 early-COVID-19 top-cited papers45. However top 1000 highly cited papers on COVID-19 have not been deeply investigated and visualized from a comprehensive bibliometric perspective. This study aimed at analyzing and visualizing these papers with a bibliometric perspective.

Methods

Search strategy and keywords

As a bibliometric study, this study was conducted by retrieving 1000 highly cited papers on COVID-19 published during 2019-2021 from Scopus. The search strategy was to extract 35 related keywords/terms on the topic COVID-19 as the main term from MeSH (Medical Subject Headings) and searching them in the fields of paper titles, abstracts, and keywords. The search query for retrieving related papers was as follows:

TITLE-ABS-KEY ("nCoV" OR "COVID 19" OR "COVID-19 Virus Disease" OR "COVID-19" OR "COVID 19 Virus Disease" OR "COVID-19 Virus Diseases" OR "Disease, COVID-19 Virus" OR "Virus Disease, COVID-19" OR "COVID-19 Virus Infection" OR "COVID 19 Virus Infection" OR "COVID-19 Virus Infections" OR "Infection, COVID-19 Virus" OR "Virus Infection, COVID-19" OR "2019-nCoV Infection" OR "2019 nCoV Infection" OR "2019-nCoV Infections" OR "Infection, 2019-nCoV" OR "Coronavirus Disease-19" OR "Coronavirus Disease 19" OR "2019 Novel Coronavirus Disease" OR "2019 Novel Coronavirus Infection" OR "2019-nCoV Disease" OR "2019 nCoV Disease" OR "2019-nCoV Diseases" OR "Disease, 2019-nCoV" OR "COVID19" OR "Coronavirus" OR "Coronavirus Disease 2019" OR "Disease 2019, Coronavirus" OR "SARS Coronavirus 2 Infection" OR "SARS-CoV-2 Infection" OR "Infection, SARS-CoV-2" OR "SARS CoV 2

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Infection" OR "SARS-CoV-2 Infections" OR "COVID-19 Pandemic" OR "COVID 19 Pandemic" OR "COVID-19 Pandemics" OR "Pandemic, COVID-19") AND (LIMIT-TO (PUBYEAR, 2022) OR LIMIT-TO (PUBYEAR, 2021) OR LIMIT-TO (PUBYEAR, 2020) OR LIMIT-TO (PUBYEAR, 2019))

The search was done on May 2021, and resulted in retrieving 151,276 papers. Out of them, the top 1000 highly-cited papers on COVID-19 limited to the years 2019-2021 were selected and ordered based on their citation numbers, and their bibliometric data were extracted for more analysis and visualization.

Database used

We used Scopus for data extraction As the greatest indexing and abstracting database for peer-reviewed scientific literature and commonly-used database for conducting bibliometric studies (46), Scopus is widely scoped than PubMed and Web of Science (WoS), as two other main indexing/abstracting databases (47-49).

Bibliometric techniques

Some bibliometric techniques such as co-citation analysis, co-authorship analysis, and word co-occurrence analysis were used for the study. The types, languages, countries of origin, affiliated institutions, and top publishing journals were determined. Co-authorship maps of collaborating countries and research institutes were depicted by co-authorship techniques. Top co-citing journals were identified by co-citation analysis. Word co-occurrence analysis was applied for determining highly frequent keywords and terms and consequent subject clusters

Statistical analysis

Data visualization was done by applying the VOSviewer software package and GunnMap. The former is used for visualizing the citation networks (authors, papers, research institutes, journals, and countries/regions), co-authorship networks (authors, research institutes and countries/regions), co-citation networks (authors, papers, and journals), co-word networks of papers as well as bibliographic couplings and subject clustering (50,51). GunnMap, as a free tool (http://gunnmap.herokuapp.com), was used for creating an infographic data map of the distribution density of papers produced by countries worldwide.

Results

General Information

The first-ranked highly cited paper with 14172 received citations was authored by 29 authors from China and entitled "Clinical features of patients infected with 2019 novel coronavirus in Wuhan, China". The paper was published in The Lancet in 2020. The 1000th highly cited paper was a note with 179 received citations. The mean rate of citations was 528.35 citations per paper (CPP). Out of these top highly cited papers, 13 papers (CPP=355.62), 980 papers (CPP=531.65) and 7 papers (CPP=398.86) belonged to 2019, 2020, and 2021, respectively. These papers included 596 original researches (59.6%, CPP=559.9), 180 reviews (18.0%, CPP=465.6), 117 letters (11.7%, CPP= 533.1), 72 notes (7.2%, CPP=517.4), 25 editorials (2.5%, CPP= 354.2) and 10 other types (1%, CPP=235.8), including short surveys, conference papers and book chapters. 997 papers (CPP=528.1) were in English and only three (CPP=595.3) were in Chinese. 965 papers (96.5%, CPP=539.8) were openly accessed and only 35 papers (3.5%, CPP= 212.9) were not openly-accessed.

Top most-productive countries, research institutes and journals

Table 1 shows the top 15 most productive countries, journals, and institutes relating to the top 1000 highly-cited COVID-19 papers. Among contributing countries, the first to the third ranks belonged to China, the USA, and the UK with publishing 418, 353, and 149 papers, respectively. Considering the CPP, Japan (1237.1), Hong-Kong (768.9) and China (684.0) ranked first to third.

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Out of the 15 most productive research institutions, 7 and 5 were from China and the USA, respectively. The top three most productive research institutions were Huazhong University of Science and Technology (N=83), Tongji Medical College (N=76), and Wuhan University (N=64). Considering CPPs, two Chinese institutions, i.e. Capital Medical University (1421.1) and Chinese Academy of Sciences (1175.1) were at the top, respectively.

Considering publishing journals, *the New England Journal of Medicin*e with publishing 66 papers (CPP=926.4), *the Lancet* with publishing 50 papers (CPP= 1293.4), and *JAMA* (*the Journal of the American Medical Association*) with publishing 49 papers (CPP=806.0) were first-to-third-ranked journals, respectively. *The Science* ranked fourth and *the Nature* and *the Journal of Medical Virology* ranked fifth in common.

Table 1. Top 15 publishing countries, journals, and research institutes active in contributing to the top 1000 highly-cited papers on COVID-19

Category	No. of Pub.	No. of Cit.	CPP
Country			
China	418	285900	684.0
United States	353	156537	443.4
United Kingdom	149	73367	492.4
Italy	104	39070	375.7
Hong Kong	51	39213	768.9
France	70	29081	415.4
Germany	66	38278	580.0
Canada	57	21496	377.1
Australia	44	23112	525.3
Netherlands	39	20795	533.2
Singapore	39	16254	416.8
Switzerland	37	16025	433.1
Spain	34	14059	413.5
Japan	32	39588	1237.1
India	22	7138	324.5
Institution (Country)			
Huazhong University of Science and Technology (China)	83	70978	855.2
Tongji Medical College (China)	76	67999	894.7
Wuhan University (China)	64	63020	984.7
University of Hong Kong (Hong Kong)	50	34219	684.4
University of California (United States)	49	21817	445.2
Harvard Medical School (United States)	46	17386	378.0
Inserm (France)	37	15035	406.4
Chinese Academy of Sciences (China)	36	42303	1175.1
Fudan University (China)	34	16672	490.4
University of Oxford (United Kingdom)	34	18735	551.0
Capital Medical University (China)	32	45476	1421.1
Columbia University (United States)	30	13359	445.3
Columbia University (United States)	30	13359	445.3
University of Washington (United States)	29	17014	586.7
Ministry of Education (China)	28	17182	613.6
Journal (2019 Impact Factor)			
New England Journal of Medicine (74.699)	66	61145	926.4
The Lancet (60.392)	50	64672	1293.4
JAMA - Journal of the American Medical Association (45.540)	49	39495	806.0
Science (41.845)	32	14559	455.0
Nature (42.778)	24	18784	782.7

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Journal of Medical Virology (2.021)	24	10109	421.2
Radiology (7.931)	22	10692	486.0
The Lancet Infectious Diseases (24.446)	21	11539	549.5
Clinical Infectious Diseases (8.313)	19	8097	426.2
The BMJ (30.223)	18	7085	393.6
Nature Medicine (36.130)	17	8787	516.9
Cell (38.637)	14	11767	840.5
Journal of Infection (4.842)	13	4327	332.8
Science of the Total Environment (6.551)	13	3202	246.3
Journal of Thrombosis and Haemostasis (4.157)	12	6598	549.8

Top collaborating countries

Seventy eight countries contributed to publishing the top 1000 highly-cited COVID-19 papers. 56 countries produced at least two and 24 produced at least 10 papers. Figure 1 and Figure 2 depicts the collaboration network of 36 collaborating countries with publishing at least 5 papers in 4 clusters. The sizes of nodes show the frequencies of collaborated published papers and lines among nodes show the collaboration density. The less the distance between two nodes is, the more the collaboration between the two certain countries is. The numbers in parentheses show the number of links a certain country had in collaboration with other countries.

The first cluster (in red) shows the collaboration between 12 European countries (including Italy (31), France (31), Germany (31), Spain (30), Netherlands (25), Denmark (25), Russian Federation (21), Sweden (20), Belgium (19), Greece (18), Norway (17) and Austria (15), two Oceania countries (Australia (29) and New Zealand (17)) and an Asian country (Iran (12)). The second cluster (in green) shows the collaboration of 8 countries (including Canada (31), Singapore (24), Switzerland (22), Brazil (20), Taiwan (17), Turkish (13), South Africa (10) and Vietnam (6)). The third cluster (in blue) includes the collaboration between the USA (35) and five Asian countries (South Korea (24), India (23), Japan (22), Saudi Arabia (17) and Indonesia (7)) and a Central American country (Mexico (14)). The forth cluster (in yellow) highlights the collaboration between China (35) and UK (33), Hong Kong (24), Israel (15), Ireland (13) and Macao (12).

Top collaborating research institutes

1893 research institutes were active in publishing these papers. 544 and 145 institutes published at least 2 and 5 papers. Figure 3 shows the collaboration network of the research institutes of 51 collaborating institutes which published at least 10 papers. Numbers in parenthesis show the number of collaborations of a certain institute with other institutes.

The network consisted of three clusters. The first cluster (in red) included 21 institutes in which 16 USA institutes collaborated with those in Hong Kong, Germany, Italy, Netherlands, and France. The top two collaborating institutes were Harvard Medical School (25) and the Chinese University of Hong Kong (19). In the second cluster (in green), 19 Chinese institutions collaborated. Of them, Huazhong University of Science and Technology and Wuhan University (28 in each) were the top ones. The third cluster (in blue) included 6 British institutes collaborating with 2 institutes from the USA, 2 institutes from Singapore, and 1 institute from Hong Kong. The first and second ranks in the cluster belonged to the University of Hong Kong (28) and Oxford University (23), respectively.

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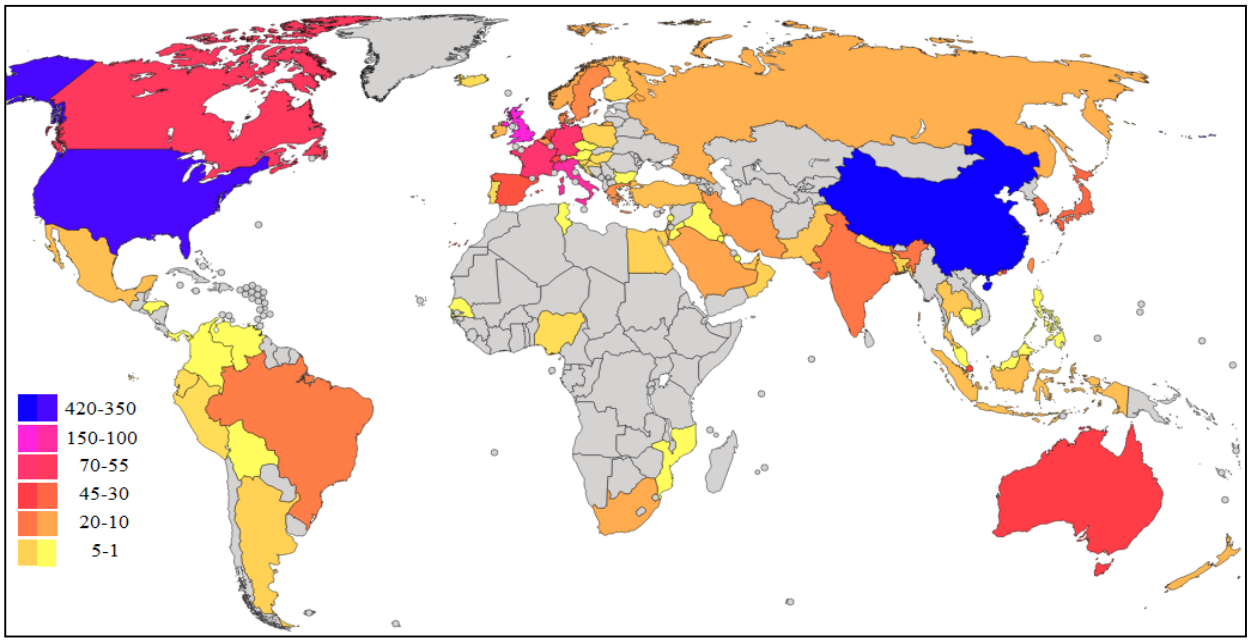

Figure 1. The worldwide distribution of the density of top 1000 highly-cited papers on Covid-19.

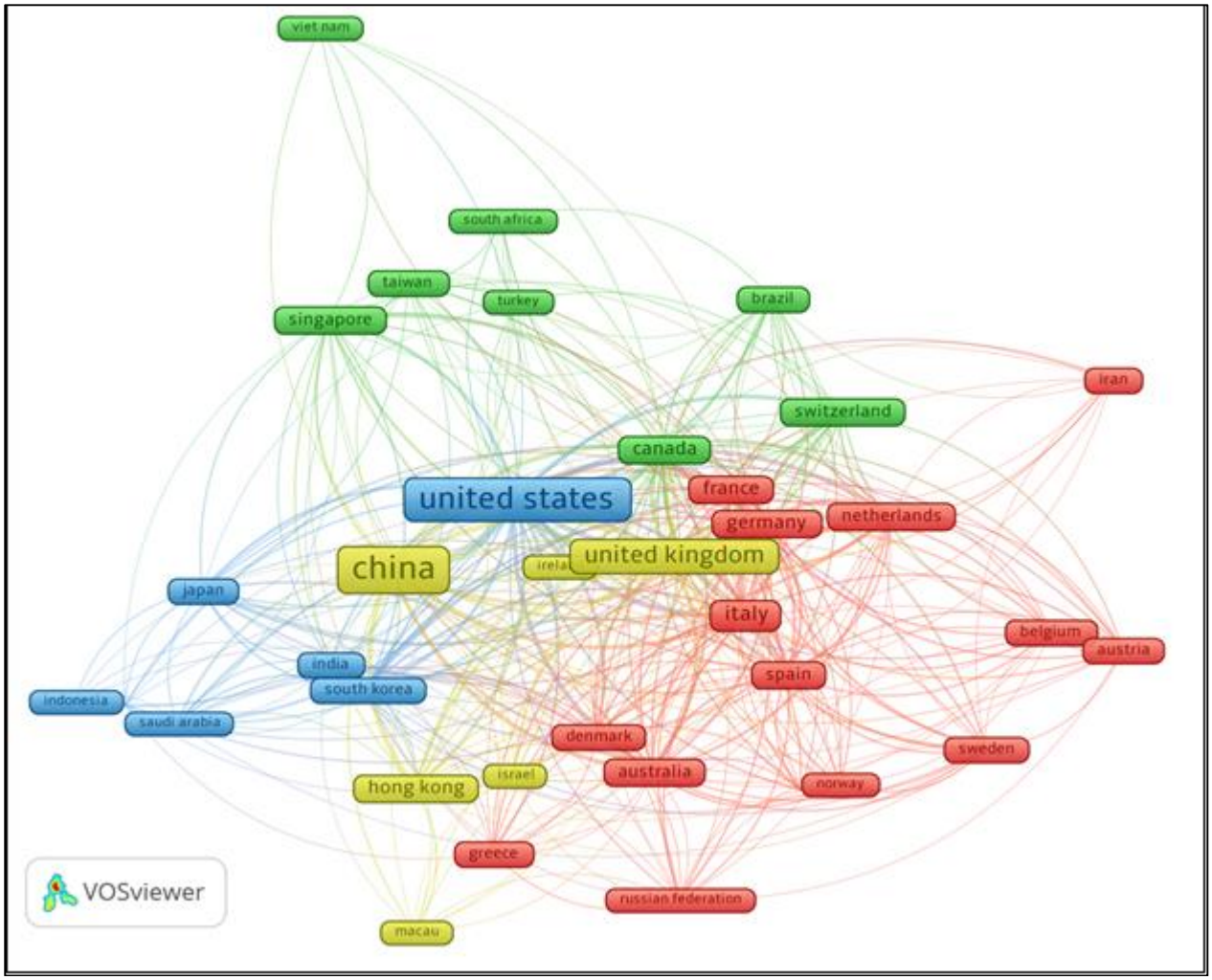

Figure 2. Collaboration network of countries contributing to top 1000 highly-cited papers on COVID-19

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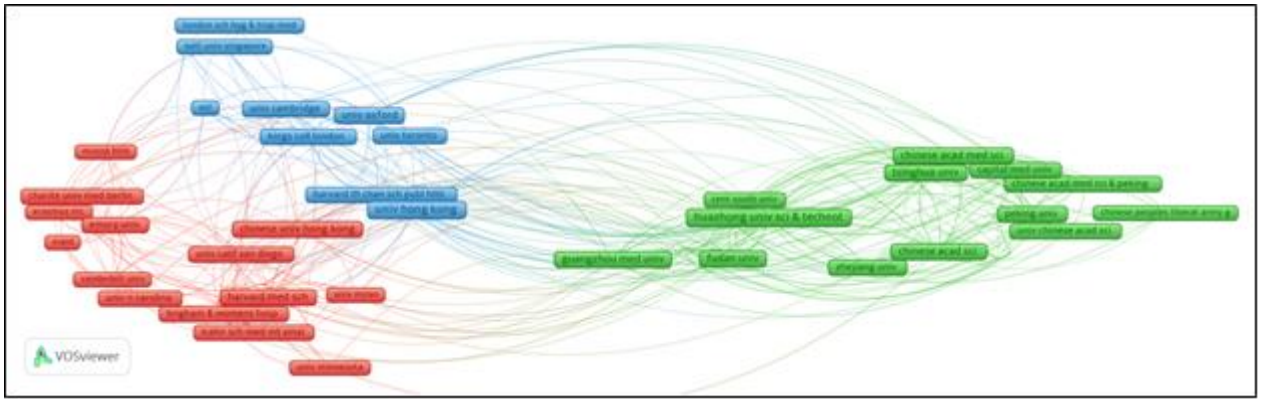

Figure 3. Collaboration network of research institutes contributing to top 1000 highly-cited papers on COVID-19

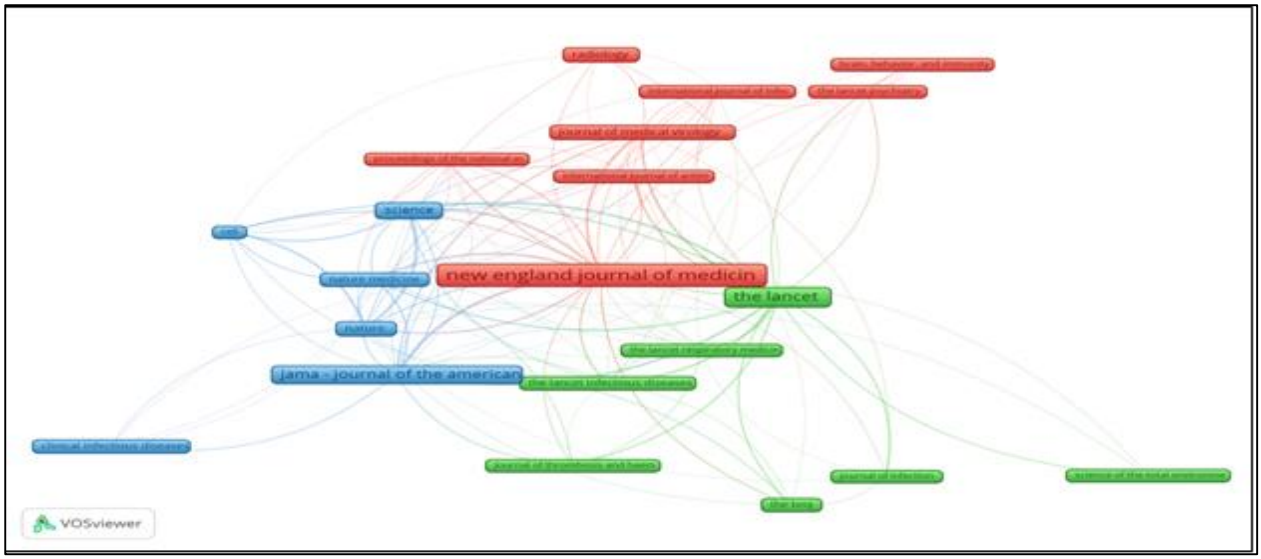

Figure 4. Co-Citation map of sources cited in papers published in top ten highly productive journals on COVID-19.

Top co-citing journals

Top 1000 highly cited papers on COVID-19 have been published in 306 journals. 126 journals published more than one paper and 42 journals published at least 5 papers. Figure 4 depicts the co-citation network of 21 co-citing journals that published at least 10 highly cited papers. The sizes of nodes represent paper frequencies and the lines between nodes show the co-citation magnitude. The shorter the distance between two nodes is, the higher the co-citation frequency between the two journals is. Numbers in parenthesis show the number of co-citations among certain journals. The network has three clusters. In the first cluster (in red), the top ones were the New England Journal of Medicine (20) and the Journal of Medical Virology (13). The top co-citing journals in the second cluster (in green) were the Lancet (19), the Lancet Infectious Diseases (14), and the Lancet Respiratory Medicine (14). The top ones in the third cluster (in green) were JAMA (Journal of the American Medical Association) (17), Science (14), and Nature (14).

Keyword co-occurrences

6024 identical keywords were used in the papers. Out of them, 1278, 682 and 352 keywords had at least 5, 10 and 20 frequencies, respectively. Figure 5 depicts the co-occurrence network of 136 keywords with at least 50 frequencies in three subject clusters. The lines among nodes illustrate the co-occurrence

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density. The shorter the distance between two nodes are, the higher the co-occurrences between the two related keywords are. The first cluster (in red) included 63 keywords related to clinical laboratory test for diagnosing COVID-19 and its clinical features and descriptions. Including 46 keywords, the second cluster (in green) dealt with risk factors and pathogenic and immunological aspects. The third cluster (in blue) included 27 keywords on COVID-19 managerial aspects and urgent preparation. Most keywords within the second cluster were occurred prior to those within the first and third clusters during the first phases of the outbreak.

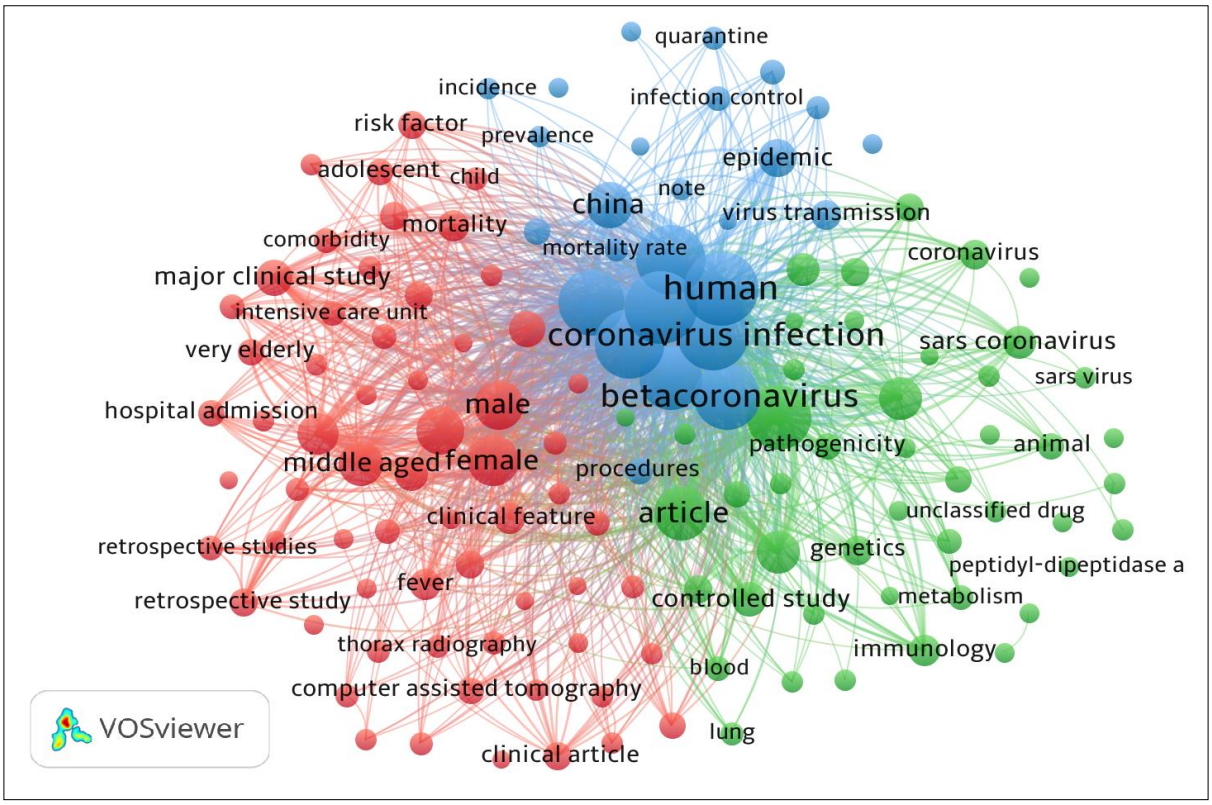

Figure 5. Key-word co-occurrence network of top 1000 highly-cited papers on COVID-19**.**

Discussion

Our bibliometric study on the top 1000 highly cited papers on COVID-19 shows the current status and trends in research on the disease. The scientific community's response to the disease was immediate as the number of citations received by the papers in these about 2 years after the outbreak clearly shows. The majority of these papers are open access that allows the easy dissemination of needed information among interested researchers and consequent increase in publications and citations. They were mainly original articles focusing on novel approaches and findings that can potentially further our knowledge of the disease.

China as the country of origin of the disease and the USA and UK as the two industrialized countries with high contamination has published the majority of these highly-cited papers. The research institutes from China and USA have a main role in publishing these papers. It is needed that the contribution of other countries and research institutes within them, including among others, African countries is encouraged in deep identification and better management of the disease throughout the World.

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Well-known and highly prestigious journals with high impact factors (the New England Journal of Medicine, the Lancet, JAMA, Science, and Nature) published the majority of these top-cited papers. These papers were co-cited by highly ranked medical journals, too. However, it is interesting that the Journal of Medical Virology has been very active in publishing and co-citing the papers in line with these journals. This active contribution will increase the impact factor of this journal in future years. Approximately, a quartile (n=245) of top-cited papers were published in the above-mentioned journals.

The majority of highly cited papers on COVID-19 have focused on clinical presentations of the virus and a clear description of the disease as we know little about COVID-19. Other related studies found such a result (40, 41, 45). Potential treatment approaches needed to be investigated in future studies by emphasizing various treatments and efficacy of vaccines.

This study offers important quantitative information on countries, institutions and journals working on the disease. Identifying the most productive countries, institutions, and journals can help potential researchers collaborate with researchers from pioneering countries and institutes and contribute to top journals for making influential works on COVID-19. Published and cited in different journals, the highly cited papers on COVID-19 reflect the complexity of the disease as well as the multidisciplinary nature of research on the disease.

Conclusion

To our knowledge, this study is the first bibliometric study on the top 1000 highly cited papers on COVID-19. We hope that the study is beneficial to researchers in identifying important topics, active producing agents, and existing gaps in the literature on the disease. Despite some limitations, including database selection and citation-based biases, this study can be a reference for COVID-19 researchers and a guide for conducting other bibliometric studies on COVID-19 papers. Interestingly, highly cited papers on COVID-19 are studied from altimetric perspectives for considering their attention in social media for detecting public concerns about the disease.

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Conflicts of Interest

The authors declare no conflicts of interest.

Ethics

This study has been ethically approved by the Ethics Committee of Hamadan University of Medical Sciences with code number: IR.UMSHA.REC.1400.006.

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